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U. S. DEPARTMENT OF AGRICULTURE

Forest Service

ANNUAL REPORT OF

INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION

FOR 1940

Ogden, Utah

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EXPERIMENT STATION

REPORT FOR THE CALENDAR YEAR 1940

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION

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January 27, 1941

REPORT OF THE INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION FOR THE CALENDAR YEAR 1940

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BYPRODUCTS OF RESEARCH

"I assert that the encouragement of scientific investigation and the spread of scientific knowledge by largely inculcating scientific habits of mind will lead to more efficient citizenship and so to increased social stability."
-Karl Pearson.

The avowed function of science is the discovery and classification of facts and the recognition of their significance, but science also contributes accomplishments which never appear on project status sheets or in publications of results. Some of the byproducts are merely incidental to the daily effort of research. Others are manifested in social responses which are far beyond the intended scope of a given project or program but which, nevertheless, are synthesized from seemingly unrelated findings of specific studies into important action programs.

Research at the Intermountain Forest and Range Experiment Station is directed primarily toward the discovery and classification of facts concerning the water, timber, and forage resources of the Intermountain Region. The aim of its program is to develop methods of improving deteriorated resources and of utilizing resources, once restored, in ways that will enhance rather than lessen their value. Important progress in factual research has been made by this Station during the past 30 years, the most recent of which are described in the divisional statements in this report. But through the years the Station has also contributed important byproducts of research which, because of their far-reaching implications, merit a place as preface to the statements on specific projects.

Traditionally, the research man is the one member of society who shrinks from contact with the outside world so as to devote himself more fully to his investigations; but the practical reality of the present day makes such contacts unavoidable. The research man is too useful a member of society, too greatly in demand, to be left unmolested in his cubicle. He finds himself with a double responsibility which works a mutual benefit, for in meeting and talking with

people, making known the results of his researches, he broadens his own understanding by coming to appreciate their points of view. And so he converses informally in the field, along the roadside, in town or city, with townsmen, farmers, loggers, and stockmen; he conducts tours of inspection over range study plots, forest nurseries, and mountain watersheds; he appears on the lecture platform of churches, schools, scientific societies, and service clubs.

In these various associations wildland administrators, resource users, and the general public have come to respect the judgment of the research man and to assimilate some of the concepts developed by his investigations. Through the years the numbers of established facts have been multiplied. Today, basic principles and concepts are not only more clearly defined but some have grown into the public consciousness and are now integrated into the social philosophy and culture of the region.

As a specific example, let us consider the progress in public understanding of the influence of plant life upon a mountain watershed. Many experiments and countless observations in all parts of the world have shown that the crowns of plants, woody or herbaceous, lessen the impact of storms upon the soil, and that the stems and litter at the ground surface and the root systems within the soil encourage rainfall to sink in rather than to wash over the surface and to hold and build up the soil rather than permit erosion. Conversely, time and again it has been found that the stripping of vegetation on steep slopes by fire, cultivation, or trampling and overgrazing have been responsible for catastrophic mountain floods.

There is a growing public interest and sharpened consciousness on the part of wildland managers in this region in the relationship between loss of plants and soil mantle and accelerated erosion and destructive floods. The efforts of research are back of this interest to an important extent. To illustrate, the pioneer experiments at the Great Basin Branch Station have contributed much not only in facts but in the education and understanding of a large number of people who, over a period of years, have visited the watersheds upon which the experiments were being conducted. The enlightenment of the general public through these visits probably has been a more far-reaching influence than the results of the studies as issued in strictly scientific publications.

Knowledge of the important relationships between the vegetation, the soil mantle of the watershed and the stream regimen has spread beyond the realm of scientific arcana, beyond the technical stock in trade of the land manager, into the public consciousness. True, its appreciation has not yet attained anything like full stature, but the vigor of its growth bespeaks abundant health and makes a contrast to the public indifference of a few decades ago. Today, in the Intermountain region there is a mounting demand that wild lands be managed for the best interests of the public at large. The public is demanding

that important watersheds be brought under control, which has resulted in a program of watershed acquisition by communities, counties, and the Federal government for the purpose of insuring application of the best management practices.

Consider as another example the growing awareness of the importance of soil to the range. Once, not so long ago, the range manager and user saw only the forage plants. The plants were what the animals subsisted on, and therefore were thought to be the limiting factor in management. No particular consideration was given to the multitude of other factors that operate indirectly, because they were either unknown or thought to be of little importance. So long as the forage plants grew tall and thick, all was well. It was not noticed that on steeper slopes under certain conditions measurable quantities of soil were slipping away from the roots. Even when the grass became sparse and short, examination was not critical enough to reveal how much of the soil, the best of it, had been worn away--it was only the dry years, and the grass would thicken up with moisture.

But the research man, because of facts that were being discovered and the relationships and principles which he formulated, was able to recognize that the basic support of the vegetation was being lost. He became aware that the well-known relationships between plant and soils are reciprocal, that the plant cover not only protects the soil from erosion but that erosion caused by soil disturbance, may bring about impairment of the plant cover and eventual destruction of the range. He saw that even when vegetal cover was satisfactory by customary standards the soil could wash away, perhaps not in quantities of flood magnitude but much faster than it could be renewed. In time this washing of soil must result in loss of plants, the loss of plants would result in acceleration of soil loss, and further soil loss would result in the losses of more productive vegetation, and so on, in a destructive downward spiral. The undesirable end results of these processes might be delayed, but if the processes were continued the end results would be just as inevitable as if the vegetation were destroyed at once. The many ramifications of the reciprocal relationships between vegetation and soil are being further investigated by the research man but, what is of importance in the present discussion, his awareness has been passed on to the land manager and is already receiving consideration in land management practices.

Another type of research contribution, which is little appreciated by the man on the street, is the synthesis of known facts, it may be from the most unrelated sources and in the most chaotic disarrangement, into a meaningful whole.

Such a synthesis is illustrated by this Station's work on the problem of floods which, until a few years ago, periodically had been causing great damage to the communities at the base of the Wasatch Range. Careful observation on the ground, together with gleanings from such diverse sciences as geology, plant ecology, and hydrology, provided a fund of data from which the final synthesis was made. Piece by piece the bits of evidence were fitted together into a reasonable explanation of the cause of the floods and a practical action program to solve the problem. The achievement was the more notable because, as has so frequently been the case in scientific advance, first it was necessary to overcome a formidable mass of prejudices and fixed opinions hallowed by supposedly scientific authority which regarded the floods as normal phenomena, as natural and as much a part of the common citizen's everyday experience as the familiar outline of the mountains themselves. But, divorced from preconceptions, the evidence showed the floods to be clearly abnormal, originating on small areas of watershed which had been stripped of vegetation, and further showed that effective control depended, not upon dikes and spillways at the foot of the mountains, but upon the reestablishment of the ability of the soil of these same high, barren areas to absorb moisture readily. Building additional facts upon this foundation, a practical system of cultural treatment was devised and methods were worked out whereby a protective stand of vegetation could be established. The dramatic success of this program, affecting as it did the most populous portion of Utah, provided a most effective stimulus to the awakening public appreciation of the relationships between plants, soils, and mountain waters.

For one reason or another, man has been inclined to regard his influence upon the physical world as ephemeral and of slight consequence, his marks upon the surface of the earth but fleeting. The limited experience of the individual has told him so repeatedly what the world is like that he comes to regard its appearance as something inevitable and unchangeable. It is easy for him to imagine that a weed-grown range has always been a wasteland, or a bare mountainside always devoid of trees--if only they have been barren long enough. It is easier to imagine a desert to have been a desert since Creation day than to imagine that it may be a desert because of man. It is easier, when floods come down from the mountains, to assume floods an inevitable part of man's lot since the days of Noah, rather than to ascribe a more immediate cause. Surely such vast consequences, consequences of such remote and awful origin, cannot be the fault of man--they must be acts of God!

As scientific knowledge increases, the consciousness is borne upon man that his influence on this world, far from being insignificant, is vast indeed, and that when he has fallen on evil days it has been largely his own doing. But within this consciousness there is room for more than self-condemnation and penitence: a reasonable hope for the future also finds encouragement. If man has brought himself on evil days, why cannot he bring himself on better days? If he can hurt himself on a vast scale, surely he can help himself on a vast scale also!

We are beginning to realize, as a people, that we can help ourselves, and we have some facts and proofs already to go on. We are conscious that quantity is not the sole criterion of good husbandry: an acre of land has meaning only when we know its quality, which we have learned to judge by what grows on it; and the number of livestock a man runs has meaning only when we know their condition and the condition of his range. We are conscious of the necessity for vegetal cover if the soil is to be productive, and we are conscious of the necessity for good soil if we would have vegetation. We are conscious of the practicability of the artificial planting of denuded lands and of cultural repair of eroded slopes--means of rehabilitation which, not many years ago, were scoffed at as visionary. Above all, we are aware of the need for the restoration and repair of our natural resources, and this consciousness, like the others, is growing every day.

These elements of consciousness are already merging into a positive philosophy of accomplishment based on a conviction that we can wittingly alter our environment for good as in the past we have unwittingly altered it for ill. The roots of this philosophy reach back into the facts and the relationships between facts that research has disclosed. These facts and these relationships are thus the soil from which philosophy grows, and such philosophy is therefore to be reckoned, in some measure, among the accomplishments of research--the seldom-evaluated accomplishments of research which become integrated with people's lives in ways that may make them more imposing than the sum of all the facts they spring from.

FOREST MANAGEMENT RESEARCH

One of the most serious problems in the management of the ponderosa pine forests of central Idaho is that of obtaining adequate natural reproduction on cut-over and burned areas. The present situation is far from satisfactory. On cut-over areas, even those on national forests where conservative selection cutting has been practiced, very few new pine seedlings have become established within the past 20 years. On denuded areas, planting has met with such poor success that a much-needed reforestation program to put these idle lands again into forest production is held back. Why? What is the matter with our cutting practices that we do not get reproduction? Why do plantings fail? What can be done to improve the situation? The problem is not a simple one; no answer is evident on the surface. It has led the Station into a broad basic study of pine regeneration, and it is in this field that considerable progress has been made during the past few years. In the silvical study of factors affecting the natural reproduction of ponderosa pine, pertinent information has been obtained on (1) seed supply - the quantity of seed produced, its quality or viability, and the distance it is dispersed from seed trees, and (2) the role of competition of native vegetation. In the study of methods and factors in artificial regeneration, further tests have indicated desirable seed storage practices, and field plantings and seedings have demonstrated procedures that promise to increase survival.

SILVICULTURE

Seed Supply. In good seed years, such as 1934, 1936, and 1940, ponderosa pine stands in central Idaho produce quantities of seed that would seem to provide abundantly for regeneration. The following table gives a comparison of the seedfall of ponderosa pine in recent years, as measured by the numbers of seed caught in 100 screen traps left on the ground under the three forest stand conditions listed:

Character of stand	Thousands of seed per acre				
	1936	1937	1938	1939	1940*
Virgin forest	173	14	10	7	254
Selectively cut	307	7	6	15	203
Second growth (age 70)	160	6	8	4	243
All stands (weighted av.)	248	8	7	11	223

*For 1940, numbers show seed fallen up to September 15 only.

The selectively cut stand averaged 4,047 bd. ft. of pine per acre after cutting in 1933. If the reserve were much lighter than this or if distribution were irregular, many portions of the area would have a poor chance of receiving sufficient seed. Collections of seed from 100 new traps placed out in 1940 at various distances from single seed trees and bodies of timber indicate that very little seed is carried more than 100 feet away from the parent trees. The 100-foot strip adjoining the timber received 82 percent of the total seed falling within 500 feet of the edge of the virgin stand. The traps beneath the crowns of trees received an average of 98 seeds each, while those 500 feet distant received an average of 2 seeds each. From lone seed trees the numbers are of course much smaller.

The quality or viability of seed varies widely with a number of factors including season, location, and individual tree. Studies begun in 1936 and still continuing have indicated that there is no consistent relation of quality of seed to any of the visible characteristics of a tree such as diameter, age, Dunning tree class, and crown volume. An association was found between quantity and quality production, however; the percentage of viable seed was higher for trees with large number of cones. Thus, it appears that no special consideration need be given viability of seed in selection of seed trees.

Cone crop records for 8 years on some 5,500 trees on sample plots have yielded much information on the quantity of seed borne by various sizes and classes of trees. It was found, for example, that pine trees less than 10 inches d.b.h. contributed only 3.1 percent of the total number of cones produced in 1936, although the number of trees of this size comprised 76 percent of the total. For trees 10 inches d.b.h. and larger, the average cone production per tree for the seven Dunning tree classes was as follows: Class 1 - 142; Class 2 - 81; Class 3 - 443; Class 4 - 154; Class 5 - 317; Class 6 - 22; Class 7 - 55. With a trend toward lighter cuttings in ponderosa pine forests, the question of leaving sufficient seed trees becomes of less concern, but where it may still be a factor, information as to what cone production may be expected from certain trees is of value in timber marking.

Pine Seedlings and Competition. Competition with native vegetation and with the overwood is responsible for a large proportion of young seedling losses in this dry region. This factor has been studied intensively since 1938 on a series of plots in grass, ninebark, and snowbrush types, in the open and under shade of reserve stand trees, on north slopes and south slopes. First-year mortality in 1938 (a relatively moist year) was 45 percent on all vegetated plots as against 16 percent on the companion plots which were freed of vegetation by clearing and trenching. In the second year losses amounted to 60 percent on vegetated and 15 percent on bared plots. Repeat tests in 1940 showed first-year losses of

95 percent on vegetated and 34 percent on bared plots. In 1939 and 1940 drought was the major cause of loss on vegetated plots, but was of minor importance on bared plots. At depths below 6 inches, soil moisture remained above the wilting point through the season on bared plots but dropped to or below that critical point on most vegetated plots.

The removal of vegetation was of similar advantage for all conditions of overhead shade and aspect. These factors in themselves had a significant effect upon germination and survival, however. In general, germination was better in the open than under shade of trees, and better on southerly than on northerly slopes. Losses were greater on shaded than on unshaded plots. Relative losses on south and north aspects varied with type, cover, and year. Shade and aspect influence mortality from specific causes in different ways; for instance, heat kill is higher on south exposures and in the open, deaths caused by fungi are greater on north exposures and under shade. Mortality charged to drought varied little with aspect and shade conditions. Losses among the three kinds of vegetation varied somewhat with cause of death and other factors, but the net survival was about equally poor in all three.

These results throw further light on the reason for good survival of natural seedlings in "stump patches", skid trails, and slash burn spots. They suggest the possibility of aiding establishment of natural reproduction (and of artificial seedings and plantings) by cultivation or removal of competing vegetation in other ways. They further indicate that germination and survival are usually hindered more than helped by the presence of an overwood. Until the study is completed and all angles of the reproduction problem are considered, it would be premature to translate these findings into recommendations of management practices.

ARTIFICIAL REGENERATION

Seed Storage. Germination tests in 1940 showed that ponderosa pine seed maintains its viability fairly well for at least four years under a rather wide range of temperature conditions when stored in air-tight containers. This is not true of all species--seed of some is difficult to keep viable with any known treatment, and that of others is quite sensitive to small differences in temperature, humidity, etc. But little specific information had been available as to ponderosa pine. Since this species produces good crops of seed only at irregular intervals of two to five years, it is necessary to store seed for several years to meet the annual needs of nursery and field seeding programs.

Seed stored in glass jars in an above-ground cellar yielded the best total germination--75.8 percent. That stored similarly in a garage attic, subject to a wide range of seasonal temperatures, yielded 66.9 percent. Of the seed in jars which stood outdoors in sunlight only 29.0 percent germinated; one effect of this extreme condition was to induce moisture condensation in the jars, which in turn favored the development of mold in some of them. No germination tests were made this year of seed from the three other conditions of storage included in the experiment--underground and in commercial cold storage at 32° and 0° F. All of these should be at least as favorable as the cellar storage cited above. Seed of the 1934 crop, one lot of which was included in the storage test, germinated more slowly but yielded a total as high as that of the 1936 seed.

Seeding and Planting. Following up leads developed by earlier studies, a number of systematic planting experiments have recently been made, involving source, age, and grade of planting stock, tools and technique, spot cultivation, fertilization, and date and season of planting. Summer drought was so severe in 1939 and 1940 as to induce heavy losses even with the most favorable practices and thus tend to obscure possible differences between treatments. Nevertheless, the results have been positive enough to suggest such procedures as the following to increase survival in ponderosa pine plantations:

1. Use stock with thick stems, relatively small top, liberal root development, root length at least 8 inches, preferably 12 inches; which is usually either 1-2, 2-1, or choice root-pruned seedbed stock; cull below-standard seedlings.

2. Plant in holes dug with shovel, or with mattock if latter makes holes deep enough for roots, rather than slit planting with mattock, shovel, or bars.

3. Sacrifice speed for care in handling and planting seedlings.

4. On sites with heavy brush or other vegetation, prepare spots by scalping or other treatment.

5. Do not plant in the fall unless rainfall has been adequate to moisten the top 15 to 18 inches of soil.

6. In spring operations, plant drier exposures first and plant within short period after snow recession unless continued rains extend the season.

Tests to date have not been adequate to yield a dependable measure of the magnitude of advantage that may be gained by certain of the refinements suggested and therefore it can not be said just how practicable they may be. The poor survival of both experimental and administrative plantings in central Idaho seems to warrant adoption of any reasonable modifications that will insure greater success.

Direct seeding with protection from rodents by means of screen cones has offered considerable promise in several tests made to date, and may prove to be cheaper than planting in terms of final establishment. In 1940, direct seeding yielded 15.0 percent survival at the end of the year compared to 5.4 percent for transplants on the same plots. The screens are of value not only in excluding rodents but also in reducing losses from heat and drought through the first season. The method is not foolproof, however, for some seedings have failed completely, and improvements in technique or perhaps the eliminations of rodents by other means such as poisoning must be tested. As with planting, spot scalping has proved an advantage. Fertilizers were of negative value in both seeding and planting in the 1940 tests, but further modified experiments with them are planned.

During 1941, it is planned to continue measurements of seed supply and dissemination, of natural reproduction as related to seed supply, and of the later effects of plant competition. Scheduled examinations and spring plantings will be made on certain planting plots, and new tests of direct seeding may be initiated in the fall. However, a large share of the season's effort will be devoted to the remeasurement of 20 permanent sample plots--virgin forest, selectively cut stands, and second growth-- and to the planning, direction, measuring, and recording of test cuttings on several of the virgin stand plots on the Payette National Forest.

RANGE INVESTIGATIONS

The Division of Range Research contributed importantly during recent years to the body of facts and principles being used as a foundation in building a sound and enduring grazing industry. Range investigations are under way in two major work projects - I, Grazing Management, and II, Artificial Revegetation. Because of the distinct climatic seasons in this region, range use must conform to a climatic pattern and become seasonal. The variation in climate together with diversity of topography results in difference in plant and soil responses to use. Problems of grazing management arising out of such conditions can logically be grouped under (a) summer range, (b) sagebrush-grass spring-fall range, (c) desert shrub winter range, and (d) utilization standards. Accomplishments under these projects are herein reported:

I. GRAZING MANAGEMENT

a. Mountainous Summer Range

Wide variations in precipitation and temperature from year to year and from place to place in mountainous summer ranges interpose real difficulties in the management of livestock grazing and in improving the forage by artificial reseeding. Plant species which by a specified date are well advanced in growth at lower elevations may be just well started higher up. Summer ranges on a mountain side by their very nature, therefore, are exposed in a single week to grazing at several stages of plant development. Coupled with over-utilization, untimely use has reduced the vigor of forage plants and consequently facilitated soil erosion. Weakened plants and erosion have in turn led to ecological disturbances in the plant cover. The search for information that will aid in overcoming these difficulties constitutes a major part of the research program on summer range lands.

Climatic and Plant Data from Great Basin Branch Station Summarized

A summary of climatic data from the Great Basin Branch Station has been prepared for the years 1914-1934. These data characterize the climates of a typical mountain terrain of central Utah ranging in elevation between 5,575 and 10,000 feet. Such a climatic characterization is of special significance because long-time climatic records, except for those collected at low elevations near towns, are extremely scarce, and over much of the West the factors of mountain climate, upon which the lowlands are vitally dependent for water, forage, and timber, are little understood.

Precipitation varies from less than 12 inches at the base of the mountains to almost 30 inches at the higher elevations. About three-fourths of the precipitation in the upper country is received during the winter in the form of snow, the source of practically all irrigation and domestic water in the valley, and about one-quarter falls as rain during the period May-October. Total yield of forage is correlated with precipitation, especially that of the summer months. Since wide variations in precipitation are experienced from year to year, marked variations in forage yield result. Total forage production may vary from as much as 120 percent above to 77 percent below a long-time average. The month of June is a critical period because then while plant growth is at its height, precipitation is least.

The frost-free period varies from an average of 90 days at low elevations to 80 days at high elevations, and the corresponding periods of active plant growth vary from an average of 175 to 125 days. The earliness and rate of plant development in spring are correlated much more closely to temperature than to precipitation. On the average, atmospheric temperature decreases 3.2° F. per thousand feet rise in elevation, and it has been found that range readiness is from 10 to 14 days later for each elevational rise. Correlations have been worked out between date of snow melting in spring and dates of range readiness, flower production, etc. These correlations are being subjected to further test for as yet it is found difficult to measure plant growth with sufficient precision for widespread practical application. Variation is marked from one year to another. The date of range readiness, for example, may be as much as 47 days later in one year than the next. The average date of range readiness is not directly usable in grazing management because so many years are later than average and hence if the average were used for such years the range would be grazed before it was ready. In order to allow for late years it is found advisable to graze about 10 days later than the average date of range readiness.

Early trials at artificial revegetation of range land were mostly confined to the higher vegetal zones, and, indeed, reseeding in the lower, drier oakbrush zone was considered impracticable. About 1925 investigation of the reseeding problems of the oakbrush zone was begun. Tests have shown that crested wheatgrass, smooth brome, mountain brome, and slender wheatgrass are suitable species for reseeding in this type. A number of methods have been tested in relation to costs, and the essential conclusion reached is that some degree of soil preparation and subsequent treatment to insure covering the seed are necessary for success.

Food Reserves and Ecological Studies

In order to gain a basic knowledge of the effects of grazing, a descriptive approach to the physiological functions of forage plants was undertaken in 1932. Work on mountain brome has shown that annual growth is cyclic, consisting of current seasonal growth, secondary herbage growth and carbohydrate storage, and that a three-phase cycle of root activity interlocks with these stages. Current seasonal growth begins from 1½ to 3 months before winter snow disappears in the spring; secondary herbage growth follows the production of seasonal shoots and flower stalks; and maximum carbohydrate storage occurs in autumn. Accelerated root growth occurs immediately preceding snow disappearance, at the conclusion of current seasonal shoot growth, and at the close of the snow-free period in the autumn. Except for hemicellulose, carbohydrate storage is inversely related to the rate of herbage growth. Minimum values of carbohydrates in the roots and stem bases occur shortly after snow disappearance in the spring, so it is clear that annual herbage growth is the product of current carbohydrate manufacture, and therefore that continued close utilization, reducing the photosynthetic surface, literally starves the plant to death.

Similar studies with clipped and grazed plants of mountain brome, slender wheatgrass, stick geranium, and niggerhead show carbohydrate reserves to be lower in clipped and grazed plants than in untreated ones. Forage yields and storage are lowest in plants clipped either continually or during the active reproductive period; but clipping at 4 inches from the ground level (as opposed to close clipping), even at a frequency of every 15 days throughout the season, permits favorable storage of carbohydrates. The conclusion to be drawn from these experiments is that moderate utilization under some form of deferred and rotation grazing is necessary so that valued forage plants may complete their life processes and hold their own in competition with inferior species.

In browse types fall clipping of mountain snowberry and birchleaf mahogany has shown that removal of current growth to one inch or more seems not to harm the plants so much as to stimulate growth. Heavier utilization is harmful. Correct utilization in browse types probably should be based on the more palatable herbaceous plants rather than on the browse species.

Current ecological field work at the Great Basin and analyses of study plot records show marked changes toward advanced forage types on some once depleted range lands, although as yet it has not been possible to define exactly the management practices responsible for this improvement. Another result of this study is the tentative conclusion that rodent burrowing, which is ordinarily considered wholly detrimental to the range, seems to be Nature's way of breaking up light limestone erosion pavements, thereby blocking run-off channels, checking erosion, and providing seedbeds for natural range revegetation.

Plans

During the summer of 1940 a conference was held at the Great Basin Branch Station in order to formulate tentative plans for future work on the summer range project. A two-phase program was decided on for the immediate future. One phase is a critical survey of management problems and problem areas, to assess priorities. The other phase is an ecological reconnaissance, to ascertain the factors governing the distribution of plant associations and the processes of succession, building so far as possible upon results of previous research at the Great Basin. A small amount of preliminary field work in defining ecological succession in the various major vegetal types was carried out before the close of the last field season.

b. Sagebrush-Grass Spring and Fall Ranges

Thick sagebrush on spring and fall ranges interferes greatly with handling sheep. Lambs are lost, wool is caught on snags, much of the grass under the sagebrush cannot be reached, and a large part of the naturally low precipitation is used by sagebrush instead of by grass or palatable herbs. Another problem also lies in the fact that feed valuable while it is fresh and green is either not relished after it has become mature and dry, or it produces unsatisfactory results in the livestock. Still another difficulty arises because range fully utilized year after year at the same stage of plant development decreases in its forage production. The research program for spring and fall sagebrush-grass ranges involves searching for solutions of these problems, or at least a means of circumventing the obstacles.

Managed Burning and Grazing Increases Forage Production

On areas from which big sagebrush (Artemisia tridentata) has been removed by controlled fire and this followed by managed grazing, forage production was in two years increased by 87 percent in Fremont County and by 147 percent at the U. S. Sheep Experiment Station. Greater production of grass and weeds and their greater availability to livestock were responsible for this increase. Not only has increased forage production resulted from sagebrush removal, but ease of handling livestock has been facilitated. Heavy stands of sagebrush form a barrier to livestock movements, permit heavy lamb losses by providing cover for predators, prevent usage of fully one-half of the current forage produced, and result in serious brushing of wool from unshorn fleeces. Moreover, where big sagebrush has gained almost complete control of an area, either through overgrazing, or as a result of cultivation and subsequent abandonment, it forms a definite barrier to range revegetation by either natural or artificial means.

The possibility of using fire to eradicate sagebrush was studied on two areas, one in Fremont County during the period 1932 to 1937, and one at the U. S. Sheep Experiment Station in Clark County during the period 1936 to 1940. Both study areas supported a good stand of perennial grasses and weeds beneath the sagebrush cover. These formed 39 percent of the total plant cover on the Sheep Station area and 53 percent at the Fremont County area. Both areas were of gently rolling topography. After sagebrush removal each area was given one full year's complete protection followed by conservative grazing.

Herbage production of thickspike wheatgrass, Plains reedgrass, and bluebunch wheatgrass more than doubled within a 2-year period following sagebrush removal. Bluegrasses and needlegrasses increased slightly or changed but little in production. Only one grass species, Idaho fescue, was found to be definitely damaged by fire. This species, secondary in importance on the study areas decreased 79 and 73 percent respectively on the Fremont County and Sheep Station areas. Grasses spreading by rootstocks were favored more by sagebrush removal than were the tuft-forming grasses.

Such weed species as tapertip hawksbeard, daisy, Stansbury phlox, lupine, and arrowleaf balsamroot appear to be favored and had, in two years following sagebrush removal, more than doubled in production. Phlox (Phlox canescens) and pussytoes (Antennaria microphylla and dimorpha), unimportant from a grazing standpoint, were definitely harmed by fire.

Sagebrush removal was complete on both areas and has persisted for 7 years following burning. Big sagebrush has never been found sprouting from the roots or root crown on these study areas, and only 1 to 5 percent of threetip sagebrush (Artemisia tripartita) sprouts. Other shrubs such as rabbitbrush, bitterbrush, spineless horsebrush, snowberry, and serviceberry sprout rather consistently and on both study areas were nearly as abundant 2 years after as at the time of sagebrush removal.

Sagebrush fires did not seem to inflict a sufficient effect on the nitrogen, organic matter content, pH, or water-holding capacity of the surface inch of soil to be measured with the methods of sampling and analysis used. Soil samples gathered from ten different burns, including the two study areas, and covering a period from 1933 to 1938, indicated the effect of sagebrush fires on the soil to be extremely variable. Seldom were there any significant changes in the properties of the surface inch of soil, and never below that depth.

Exposure of the soil during the summer and fall following sagebrush removal did not on either study permit serious wind or water erosion. No water erosion was evident on either of the study areas and wind erosion, accelerated during the summer and fall immediately following burning, was arrested as soon as plant growth started the following spring.

The cost of sagebrush removal, when 4-section units are treated, using controlled fire, is from 15 to 20 cents an acre. Cost records collected during 1937 indicate that approximately one-half of this cost may be charged to the use of special control fire lines and control crews that are used to restrict the fire to the area from which it is desired to remove the sagebrush. An additional charge of 5 to 10 cents an acre for loss in grazing privilege on the area for a year is appropriately charged against the cost of controlled burning.

Sagebrush removal, by using fire, has been the most promising measure of range improvement tried on the study areas, and on many other areas in Clark and Fremont Counties. Perennial grass and weed stands have been increased from 50 to 100 percent and forage production increased from 87 to 147 percent in 2 years. Reseeding has met with marked success following removal of dense stands of sagebrush. But, almost without exception, improvement has occurred where an abundance of perennial grass and weed species not subject to appreciable damage by fire existed on the area or where the area was reseeded following sagebrush removal, where total protection from grazing for a year following sagebrush removal was given the area, and where subsequent management was favorable to the retention or increase of the perennial grass or weed stand.

But sagebrush removal by fire has been an agent of range deterioration more frequently than a measure of range improvement. Pickford found promiscuous fire and unrestricted grazing distinctly destructive to range productivity. Removal of the protective cover of sagebrush has been found to permit accelerated wind erosion on sandy soils, water erosion on steep slopes and granitic soils, destruction of the remnants of perennial grass and weed stands where removal is not followed by proper management, serious reduction in perennial grass and weed stands where the major species are subject to damage through the action of fire, and loss of personal property, personal injury and danger of life where unrestricted and uncontrolled fire has been used.

The cost of removal, by the use of uncontrolled and unrestricted fire, is so low, and the promise of range improvement so bright, state statutes concerning the use of fire either lacking, or the enforcement of state and Federal statutes so lax, that many individuals are willing to gamble with their lands with the hope of getting range improvement.

Permanent establishment of good stands of perennial grasses and weeds, with scattered stands of sagebrush and other shrubs, should be the objective of a sagebrush removal program. On certain areas removal followed by proper grazing management may suffice to attain the objective. On other areas removal, reseeding, and proper grazing management may be necessary. On still other areas removal should not be permitted under any circumstance.

Proper management following removal is one of the chief factors determining success. On the two study areas not even a scattered stand of sagebrush is evident 4 and 7 years after sagebrush removal. On other areas in Clark and Fremont Counties dense stands of sagebrush have become reestablished in 2 years because of failure to reseed the area to perennial grasses and restrict grazing. Even where correct grazing management following removal was the only practice necessary, but was not provided, sagebrush has been found to come in rapidly and in a 7-year period has reestablished a dense stand.

Limitations concerning the use of fire for sagebrush removal are many, mostly imposed by the meager amount of information available concerning its effects on different areas, and under different conditions. The present status of the use of fire may be summarized in eight points: (1) Federal and state statutes regulating the use of fire should be observed; (2) the use of fire, in other than an experimental manner, should be restricted to Clark and Fremont Counties of the Upper Snake River Plains of Idaho; (3) fire must be controlled to specified areas by extensive preparations to safeguard property and life, and to confine removal to areas where success seems assured; (4) control of grazing immediately before and after sagebrush removal are essential; (5) fire should not be used on areas where a predominance of Idaho fescue exists or where the major grass and weed species are not known to be resistant to fire; (6) sagebrush should not be removed from areas with an extremely sparse cover of perennial grasses and weeds unless provision is made for subsequent reseeding; (7) exposure of soil as a result of sagebrush removal on potential erosion areas may result in serious losses through wind and water erosion; and (8) the use of fire at periodic intervals to remove sagebrush, permitted by mismanagement to return to treated areas, should be discouraged.

Caution should accompany the contemplated use of fire for removing sagebrush lest range deterioration instead of improvement be the result. Fire is a valuable tool, if intelligently used, but because of dangers involved all who are interested in conservation should sanction its use only under conditions and circumstances that are well understood.

Chemical Composition of Native Range Forages Raises Questions In Management of Spring-Fall Ranges

Variations in the chemical content of herbage furnished by native species on the sagebrush-grass spring-fall range are large, and much greater within than between species. Studies carried on in cooperation with the Idaho Agricultural Experiment Station indicate that stage of plant growth, or maturity, is the most important single factor affecting the chemical composition of range forages, even more important than the differences among species.

Herbage furnished by the principal grasses and weed species during most of the 60-day spring grazing season is rich in protein and phosphorus. At the beginning of the spring season the herbage has a crude protein content of 20 to 25 percent, phosphorus content of 0.3 to 0.6 percent, and a calcium/phosphorus ratio of from 2 to 4. By the end of the spring grazing season, however, the grass and weed herbage has declined in value until the content of crude protein is 6 to 10 percent, phosphorus 0.08 to 0.10 percent, and a calcium/phosphorus ratio of from 5 to 20. At this time shrubs furnish herbage about equal in composition to that furnished by grasses and weeds. The partially cured herbage, having wide calcium/phosphorus ratio and low protein content is probably very low in its value for milk production by ewes with lambs, and not suitable for consumption by young lambs. Because of these conditions, it may be profitable to leave the spring range 5 to 10 days earlier than is ordinarily done.

During the fall grazing season the value of cured grass and weed herbage is much lower than commonly supposed and after growth ceases during the summer the herbage deteriorates rapidly in value, even though retaining the appearance of "curing well." By the beginning of the fall grazing season its crude protein content has been reduced to approximately 3.0 percent, its phosphorus content to 0.04 percent, and its calcium/phosphorus ratio to 15 for grasses and 40 for weeds. Two vital constituents, protein and phosphorus, have largely disappeared from top growth of grasses and weeds. Shrub herbage during the same period has deteriorated, but to a much lesser degree, and during autumn furnishes forage twice as strong in crude protein and three times as strong in phosphorus as the cured herbage of grasses and weeds.

Seasonal phosphorus deficiencies may occur, and have occurred occasionally, on these range lands during the fall. The cured herbage of grasses and weeds is so low in crude protein and phosphorus content that a sheep could not eat sufficient of their forage to satisfy its maintenance requirements in these essential feed constituents. Thus, it would seem that unless grass regrowth occurs in the late summer or fall, which happens about once in 3 years, or unless shrubs make up a fair proportion of the sheep diet, that seasonal phosphorus deficiency may occur, and an inadequate amount of protein will be secured for body needs. During the fall of 1939 a phosphorus deficiency did occur among the sheep on these ranges as result of their failure to consume shrub herbage.

From these forage analyses it appears that during certain fall seasons the feeding of protein and phosphorus supplements to maintain a satisfactory plane of nutrition may be a profitable practice in management. The value of grass and weed herbage for fall feed also raises a question concerning the desirability of complete removal of sagebrush and other shrubs by fire from areas of spring-fall range.

Management Principles Established for Sagebrush-Grass Spring-Fall Ranges

Either rotation or rotation-deferred grazing of the range has been found at the U. S. Sheep Experiment Station to be essential during the spring grazing season. This results from the fundamental principle that management of sagebrush-grass spring-fall ranges is aimed at increasing, or at least perpetuating, most of the desirable species present on an area. Fall grazing, if the area is properly stocked, on the other hand, need not have any special system of management. During the period 1933 to 1940 no difference was found on the fall grazed areas in the relative merits of the two grazing systems either from the standpoint of the animal or of the vegetation.

The critical seasonal period for many plant species seems to be rather closely associated with the reproductive stage. For bluebunch wheatgrass and arrowleaf balsamroot clipping studies indicated that full use is most detrimental from May 25 to June 10, that is, during the period from the time wheatgrass flower heads appear until blooming is over and from the time balsamroot reaches full bloom to seed maturity. The many other desirable species that occupy a single site flower at different times varying from May 10 to July 1. Thus rotation or rotation-deferred management is essential to prevent use of a single group of species during their critical period year after year.

A degree of stocking of sagebrush-grass spring-fall range that will improve or maintain it is necessarily based on the maintenance or increase of desirable vegetation that is available to livestock, i.e., in the interspaces between sagebrush plants or clumps. Forage plants completely inaccessible to livestock use should not be considered in judging grazing capacity.

A monthly forage allowance per sheep of 0.036 forage acre, where the range survey uses the point-observation-plot method, or 150 pounds of forage, air-dry weight, where the survey is made by the weight-estimate method, is needed. This base allowance should be varied for class of animal using the area from 60 percent for dry ewes to 130 percent for ewes nursing 40- to 60-pound lambs.

An allowance of 3 to 4 surface acres per sheep for the 4-month grazing season (2 months spring and 2 months fall) should be made on areas of good sagebrush-grass range, with palatable grasses and weeds about equally abundant and jointly forming 45 percent of the total production. On range in moderately good condition 6 to 8 surface acres would be required, and for range in poor condition where shrubs, chiefly sagebrush, make up 85 percent of the total production, 12 to 15 acres would be required. It is assumed that in grazing the area one-half the use is in spring and one-half in fall.

It has been made clear that spring grazing may well begin when bluebunch wheatgrass is 2 inches in average height. At this time such palatable perennial weeds as lupine, arrowleaf balsamroot, pentstemon, and tapertip hawksbeard have not yet begun growth, and such early blooming perennial weeds as cogswellias and violets have not yet begun to bloom. This stage, during the period 1923 to 1940, inclusive, was reached at the average date of April 19, but varied 37 days between early and late seasons. The spring grazing period properly ends about June 20, because before that time perennial grass and weed herbage begins to cure, and ewes and lambs foraging on it generally begin to lose their "bloom." The fall grazing season may well begin about October 1, and end at the time of permanent snow fall, about December 1.

When a range is properly stocked, and grazed under rotation management, it has been found that bluebunch wheatgrass will be utilized about 30 percent; balsamroot 30 to 35 percent; secondary palatable weeds and fine grasses such as pentstemon, tapertip hawksbeard, Sandberg bluegrass, Nevada bluegrass, and needle-and-thread 50 to 55 percent; and rabbitbrush or sagebrush not at all or not to exceed 1 or 2 percent, utilization being measured as soon as grazing is over in the spring season. For the areas grazed first in the rotation, that during the first period of the spring season, the utilization of any species may be as much as 10 to 15 percent higher than stated. At the end of the fall grazing season the appearance of the properly stocked range will be highly variable, owing to highly variable fall palatabilities of different forage species. Bluebunch wheatgrass will be utilized from 30 to 50 percent; Sandberg bluegrass, Nevada bluegrass, and needle-and-thread from 60 to 80 percent; sagebrush from 0 to 3 percent, rabbitbrush 2 to 10 percent, and bitterbrush 0 to 50 percent.

Palatable secondary perennial weed species such as pentstemon, daisy, astragalus (Astragalus stenophyllus), lupine, and tapertip hawksbeard appear to provide the most reliable indicators of use of sheep ranges in the Upper Snake River Plains.

Plans

Grazing management data from one complete rotation cycle are being studied intensively to determine what short of re-orientation may be most profitable. Since some data indicate that rotation of grazing use in the spring period may be as satisfactory as deferred rotation grazing, it is necessary to analyze the data bearing on this point as early as possible. In addition, cooperative plans with the University of Idaho are now being completed for the study of chemcial composition of major forage species at different periods of growth. This promises to be a fruitful field of research as to needs of animals at different periods of the grazing season. Eventually digestion tests will be required.

Removal of dense stands of big sagebrush from vast areas of spring and fall ranges is so tremendously important as to require urgent attention. It is planned to test not only burning but railing and any other feasible method to remove or reduce the sagebrush stands to an effective degree.

Big sagebrush (Artemisia tridentata) in dense stands, is one of the most important problems on over one-half of the 96 million acres embraced in the sagebrush-grass type. Successful natural or artificial rehabilitation of such areas is faced with the task of sagebrush removal. Approximately one-half the current soil moisture supplies are used in the production of big sagebrush herbage, worthless as spring forage and of limited value for fall feed.

c. Desert-Shrub Winter Range

The winter ranges generally of the Intermountain region are in a state of serious deterioration. Because of this, sheep during most winters fall off in flesh weight and produce less wool and lower lamb crops than are produced on well-preserved ranges. In winters following drought, especially when there is much snow, death losses are likely to be heavy, even though considerable supplemental feeding is done. Improving forage conditions by conservative range use not only reduces costs but increases financial returns. Also, the infrequency of natural watering places has caused herds during winters with little snow to over-utilize the forage close to water. This has given rise to the need of investigating whether hauling water might prove to be economical.

Good Range Management Yields More Forage and Greater Livestock Returns

Investigations at the Desert Range Branch Station have shown clearly that ample good forage, thrifty livestock, and conservative range use constitute sound bases on which to build a stable livestock industry. All these factors are essential and no one by itself is sufficient. Contrary to general practice and the opinions of many stockmen moderate grazing is justifiable from a purely economic point of view and from a biological point of view it is absolutely mandatory in order to preserve the good forage plants.

Sheep on moderately grazed ranges where ample forage is available throughout the entire season go through the winter in 10 to 12 pounds better flesh than do those on heavily grazed areas. Small bands of sheep in lightly grazed paddocks gained 4½, 3½, and 6 pounds per head, respectively, during fall, winter, and spring seasons. Under moderate use the gain was 2-3/4, 3, and 8-3/4 pounds per head. In paddocks subjected to heavy grazing the ewes lost 1-3/4 pounds during the fall and 2-3/4 pounds in winter, and during the spring they showed a gain of 3-1/4 pounds. In general, sheep grazed on

range under light and moderate use come through each of the three seasonal periods approximately 5 pounds per head better than those on heavily grazed areas. Moderate grazing stimulated an increased production of 0.93 pound of wool per head above those on heavily grazed areas. The lamb crops are 3 to 8 percent greater, death losses of ewes from malnutrition 3 to 5 percent less, and the need for supplemental feeds in the form of cottonseed cake, corn, hay, etc. is much reduced. In fact, during the last 6 years no supplemental feeding has been required on the moderately grazed experimental range, whereas during this same period the majority of sheep owners whose flocks have wintered in the vicinity of the Desert experimental range have as an average fed supplements during 4 of the 6 years.

Net income per ewe on the moderately grazed areas was approximately 50 cents greater than that obtained on heavily grazed range. About half of this amount--23 cents to be exact--resulted from an increased yield of wool, which is approximately 1 pound for each mature ewe greater on moderately grazed ranges than on heavily grazed ones.

In 1936-37 two comparable flocks, one on the moderately grazed experimental range and the other on the adjacent open range which is heavily grazed gave the following results: The total net income on the moderately grazed Desert experimental range was $1,200 greater for the herd kept inside than for the one wintered under outside conditions. This greater net income included a saving from lower death losses, smaller cost of supplemental feed, and the greater yield of wool. During the following year these two herds were alternated, that is, the herd previously grazed outside was put inside, and vice versa. The income from wool alone this year was $825 greater in favor of the herd on the inside, which had good ample feed.

Range was benefited by conservative grazing use in a very striking manner. Forage production more than doubled in 7 years on ranges moderately grazed. In point of time the first apparent improvement in range condition resulted from increased vigor in the existing plants; later many new seedlings became established, thereby thickening the stand. In 1936, 3 years following the commencement of moderate grazing, each 1,000 forage plants were producing from 5 to 10 times greater quantity of forage than a similar number of plants on the adjacent heavily used areas. Not only is a greater quantity of forage produced, but the quality is also much enhanced because the better forages such as Indian ricegrass, black sage, and white sage are the ones to increase in vigor and numbers. That the best perennial forage species are the ones to increase under moderate use is a strikingly important point.

Another very interesting and valuable point is that moderately grazed ranges recovered as rapidly and were found to be maintained in about the same productive state as those which had been under total protection for the 7-year period, 1933-1940. Also, little difference could be noted in the condition of the vegetation or soil between range properly grazed and range not used at all. Moderately grazed ranges were shown to be able to stand drought much more effectively than ranges heavily grazed. Forage production on a moderately grazed paddock in 1940, the driest growing season since the establishment of the station, was only 28 percent less than the production of the same paddock in 1938, when precipitation was much better than average, and when forage production was the greatest since 1933 when the experimental range was fenced. During the same period the forage production on an adjacent paddock grazed 25 to 30 percent heavier decreased 61 percent, and showed signs of deterioration in vegetation and soil. Drought and moderate grazing together caused less than half the decrease brought about by the combination of drought and heavy grazing. If the effects produced are assumed to be separable, which is only partly true, heavy grazing alone resulted in 33 percent decrease in forage production. Since moderate grazing was combined with drought to produce a decrease of 28 percent it seems likely that the net effect of drought alone was less than 28 percent.

Winter ranges have been considered by many stockmen as serving the utility of "carry over" for their livestock from one summer to another. Little consideration was given to the welfare of either animal or range. Apparently it was assumed that so long as the animals survived, without excessive death losses, the winter was a profitable one, - or at least a satisfactory one. Thus developed a phrase characteristic not only of conditions on the winter range but also of their philosophy, "If we can get by the winter." They placed their hopes of profits and success on spring, summer, and fall ranges and looked with gloom on the winter period. On desert winter ranges competition for forage was excessive, the practice of sound principles of management was rare, and areas producing more than average amounts of forage were sought by numerous herds which congregated on these areas in an effort to survive. Forage became more and more scarce until much low-value feed and some that was poisonous had to be consumed. Malnutrition in the livestock became accentuated, and in especially bad years losses from "bighead" and general debility mounted disastrously.

Contrary to the "get-by" philosophy, the winter grazing period is one of the most important and critical periods throughout the entire year. Malnutrition is always critical, especially when it coincides with periods of breeding and pregnancy. When in addition to malnutrition, accumulative poison from grazing on horsebrush occurred, this was extremely deleterious. Lamb and calf crops are lower, wool production smaller, and when malnutrition is prolonged death losses become excessive. After the animals are greatly

emaciated, a full season is required to restore them to a thrifty condition. Until this is done, reproduction and other vital functions do not operate normally. Under poor forage conditions, income is lowered and operations costs are excessive.

Animals and plants, like man, perform more efficiently if they are in a thrifty condition and under proper care. If forage plants are allowed to build up ample food reserves they become thrifty and produce considerably more and better quality forage than do abused plants. Nature provides plants with a food-manufacturing device which under normal conditions provides ample reserves to maintain the vigor of the plant with a surplus which may be used for forage growth. Such a surplus may be used with little if any harm to the plant. If more than the surplus is used the plants are weakened and when kept long under continued extraction, they die. As in the fable of old, this ambition for more and more immediate profit at the expense of productive capital induces many stockmen to "kill the goose that lays the golden egg." Ranges in good condition which means truly vigorous plants of good forage species, are the geese which lay the golden eggs valuable in livestock production.

Field Day

Field days held at the Desert Range Branch Station late in September were well attended by stockmen and others, who expressed themselves as being well repaid. Separate programs were prepared for the Utah and Nevada groups. The Utah field days, September 24 and 25, were attended by 110 people, about 75 of whom were stockmen; the Nevada days, September 26 and 27, had an attendance of 61 with about 45 stockmen. The excursions were conducted in cooperation with the State Agricultural Extension Services of Utah and Nevada. High interest was shown in those experiments which compared (1) the effects of moderate grazing and drought on the one hand with those of heavy grazing and drought on the other; (2) the effects of complete protection with those of moderate grazing; and (3) the animal response and increased profits derived from moderate grazing.

Hauling Water to Livestock Beneficial

An ample supply of water easily accessible to livestock was found at the Desert Branch Station to be of prime importance in maintaining desirable forage and animal condition. In 1935 experiments were initiated to determine the feasibility of trucking water to sheep and cattle. These studies indicate that water can be hauled a distance of 10 to 12 miles to sheep or cattle on a profitable basis as justified by improved condition of livestock and smaller death losses.

On the winter ranges throughout western Utah and Nevada permanent watering places are few and widely separated, which means that the greater part of the area is grazed during periods when snow is available for livestock water. During dry periods in the fall and spring and in winters when snow is scarce, forage around permanent watering holes is heavily grazed and livestock are forced to travel great distances to feed. Sheep often are trailed several miles between the last remnant of snow in the hills and the valleys where some feed is available. Frequently this distance is so great it requires a full day to make the trip. Sheep are forced to remain two days away from snow and on the second day many of the animals are too thirsty to eat such dry meager forage as is available. During these periods all animals lose flesh rapidly; many of them becoming too weak to travel, perish from thirst and starvation. Cattle trailing to and from feed and water during the accentuated dry spells become emaciated and weak. Damage to the range from excessive trampling is severe. As a result forage around many of the permanent water holes has been seriously injured.

During the unprecedented dry fall and early winter of 1939-1940 snow was extremely scarce and permanent and temporary watering holes were insufficient to provide water near enough to forage for many of the herds. As many as seven flocks of sheep were trailed day after day to a single water hole. The trail became so trampled that vast dust clouds hung suffocatingly over the flocks. On each trip to water several animals would perish owing to these aggravated conditions. A number of sheepmen, former cooperators at the Desert who had been induced to haul water while grazing on the experiment station, later obtained equipment and trucked water to their flocks on the open range. By this means they avoided the heavy concentration around the water holes and their flocks were grazed at 8 to 12 miles distant on good fresh feed. The sheep, thus furnished water, remained in thrifty vigorous condition, the losses were small, and the operators estimated that their wool crops were 3/4 to 1 pound greater than flocks trailed to and from water.

The troughs used were easily portable, and could be moved rapidly between successive waterings. The flock was watered every second day and each animal was permitted to drink as much as it desired. Records indicate that sheep thus treated require during the fall approximately 0.6 gallon per day. During cooler weather the amount required is less than 0.5 gallon per day. Cattle were found to require from 5 to 8 gallons a head per day, depending on the condition of forage and dryness of season. Frequently during winter periods when ample snow is on the ground it becomes dry, crusted, and frozen so hard that animals are unable to obtain enough to supply sufficient moisture for their systems. During these dry, cold periods sheep at the experiment station preferred water and each day consumed about 0.35 gallon a head.

In addition to the benefits derived by the animals, trampling of ranges by livestock is reduced to a minimum. Small localized areas are injured but these quickly heal. If the practice of hauling water were adopted extensively it would no doubt prove profitable to both animals and range.

Plans

The present experiments at the Desert Range Branch Station will be continued and those which are being conducted to determine the response of animals to intensity of grazing will be amplified to include more information on wool weights and lamb crops. During the coming year detailed and comprehensive work plans for the Desert Branch Station will be completed. If possible, arrangements will be made to remap and estimate the 27 enclosures established in Nevada in 1932 and 1938 to determine the amount of range recovery which has taken place since the enclosures were established. This latter work will be done in cooperation with the University of Nevada.

d. Range Utilization Standards

The continued deterioration of managed ranges in some cases and failure to make expected recovery in others have forced an inquiry into the degree and manner to which ranges can be grazed without injury. Steep slopes and soils susceptible of erosion have permitted deterioration on many ranges that were thought to be only moderately grazed. How to establish standards for judging utilization under widely differing conditions has been investigated in an exploratory way.

Standards in Range Utilization Now Established

Within the last three years standards in range utilization have been set up for all the major range forage types within Region 4. These standards are based largely on approximate judgments that have developed during the past 35 years of grazing management, together with such technical information as has proved applicable to the various range types. These standards first describe range types in satisfactory and unsatisfactory condition, and then set up tentative limits of use for important key species. They also consider various criteria for adjudging range conditions and for equating the close interrelationship of soil and plant cover.

Continued range deterioration on many forest ranges, together with technical findings, particularly on growth cycles and physiological responses of major forage species, has demonstrated the need for scaling down some previously established concepts of range use. The maximum use for key forage species on stable soils on high summer range land is established at 70 percent of the current herbage,

instead the 80 and 85 percent previously thought satisfactory. Lower values have been suggested for unstable soil types, deteriorated ranges and steep slopes. This latter point, long recognized as an important factor in determining the degree of use an area can reasonably withstand, has been in the past, too often taken as a matter of fact and not critically scrutinized in range management operations.

Utilization standards for some eleven important forage types are set forth in the Range Utilization Handbook that was prepared and issued in 1939. The conditions found and the needs for handling additional forage types have since been analyzed and written up. The preparation of this handbook has been the work of several individuals. It has been done in cooperation with the Division of Wildlife and Range Management, Region 4, and the Intermountain Forest and Range Experiment Station, and represents a summation of ideas and information from these people as well as from a number of rangers and supervisors of the region. At the outset it came to be realized that the establishment of reliable utilization standards for all vegetational types is practically impossible. For many phases, information is simply not available, particularly regarding resistance to grazing of many important species, and the influence of slope and soil conditions. The standards as set forth in the handbook, however, represent the best of such information as is available, and in instances where specific information is lacking represents the best judgment of those range men who are most familiar with the problems.

Range utilization standards have developed as the result of a growing consciousness of the range problem which is more or less counter to the pioneer attitude of the "unlimitedness" of the range resource. In some cases standards set up have not sufficiently restricted use; admittedly in other cases they may not be absolutely accurate. They are of course not final or fully refined. Standards will continue to grow and be modified so long as information on range problems continues to accumulate. The development of more specific standards both for broad and local forage types is the range man's responsibility--the responsibility of both research and administrative men.

The handbook presents little new information. In the formative stage of setting up utilization standards it has been the aim merely to amass, evaluate, and organize existing knowledge and make this information available to all range men rather than to initiate new technical studies. A more reliable basis for guidance in range management practices has been sought. In its full scope the handbook covers three major phases that are intended not only to set up standards but to help clarify the range utilization problem and to standardize methods and procedure among range men. These three phases may be designated as follows: (1) concepts and methods of studying utilization; (2) criteria for judging range conditions; and (3) range utilization standards for broad forage types.

The information brought together has been welcomed by range men generally. Its value, however, lies not in its acceptance but in what use is being made of it. Rangers and supervisors have found it useful. They have followed the methods and standards set up in the handbook for checking on the degree of utilization on range allotments and forage types and have used standards concept as a guide for studying local types and developing new standards for these areas. From the standpoint of future range work, however, probably the greatest good has come from the standardization of methods and procedure. This alone has done much in developing a desired degree, though not necessary a stereotyped form, of unification of thought regarding utilization problems.

Utilization standards, while not fully adequate for all range types, have helped to develop a consciousness of the range problem. The standards have served to call attention more strongly to actual current utilization rather than depending to such an extent on secondary indicators as vigor of plants and "highlined" conditions of browse. The value of secondary indicators must not be minimized, but they often are too slow in operation to detect undesired trends or to serve as a basis for establishing satisfactory range management practices. The use of secondary indicators or other criteria of range conditions such as "highlined" browse, while helpful is not wholly reliable. These indications may become apparent so gradually that range deterioration is well advanced before the indicators have fully manifested the trend. Some errors in established concepts have also been pointed out. Many range men who once maintained that 75 to 85 percent current utilization was not excessive for certain key species have, after actually making a few utilization checks, vigorously refuted their earlier standards and now maintain that previous standards were too high. The standards have called attention to soil erosion, and soil and plant conditions for ranges in satisfactory and unsatisfactory condition; definite criteria that have too often been taken as a matter of fact.

What lies ahead in the study of utilization standards? Unquestionably a great deal. Little is known of numerous local range types, and concerning a few rather extensive ones little information has as yet been obtained. Physiological responses and growth characteristics of many important range forage plants are practically unknown. This is also largely true for resistance to grazing and factors underlying resistance, whether morphological, physiological, or developmental. Present standards need to be further refined and new ones added. The role of soils in determining proper utilization standards needs more careful study. It is known that the better plant types are associated with better soil conditions, but the relation of fertility levels to rate of water infiltration, forage production, and the plants' resistance to grazing--all interrelated phases of the range utilization problem--is not fully understood. Other phases of soil and site conditions, such as depth, organic content, slope, texture, and profile need to be more fully investigated

before many range problems can be solved. Solutions must, at least in part, precede the formulation of standards as to what are satisfactory range conditions and what is proper use of a given range.

Volume-Height A Doubtful Utilization Method

Volume-height relationships for some ten important summer range species have been observed over the last three seasons. Three things are indicated by these studies: (1) The growth form of many species, particularly tall-growing bunchgrasses, is not uniform from year to year. This necessitates making volume-height tables for each year, a task which is very laborious and time-consuming if the samples are adequate to insure the tables being representative. (2) Volume-height scales have not been found suitable for weed species which produce many leaves and side branches from the main stem. With this class of forage it is possible for stock to remove a large percent of the volume without reducing the height. (3) Volume-height scales do not simplify utilization determinations. Although scales may reliably interpret the degree of use from stubble height, the error in arriving at average stubble height may be as great as the error in estimating percentage utilization directly for the same plants or plots.

Observations on the effects of grazing on subsequent growth shows that close current utilization results in reduced growth the next year. For slender wheatgrass this was found to amount to 32 percent for fully utilized as compared to nonutilized plants. Similar comparison for mountain brome plants showed approximately 25 percent reduction. Moderate use (35 to 50 percent) resulted in but slight reduction for either species. Continuing these observations through the second year, after one year of uniform treatment, it was noted that mountain brome plants subjected to full use, 70 to 80, and 35 to 50 percent utilization at the time the study was started gave yields essentially alike, but yielded only approximately 60 percent as much as plants which were nonutilized. Later observations indicate that year after year the smaller plants tend to be more closely utilized than larger ones. The rate of recovery following severe treatment was found to be a function of both species characteristics and site conditions.

Needs and Plans

The needs and plans for the utilization standards project are discussed in detail in problem analysis and work plans prepared and submitted to the Washington office for approval. In addition to the proposed studies which are directed at basic phases of the utilization problem, there is need for continued observational studies and for making detailed inspection of range allotments and numerous range forage types, many of them local but important to proper range management. Also there is need to continue studies in methods and means for more accurately determining the degree of utilization both in experimental investigations and for range administration.

II. ARTIFICIAL REVEGETATION

Early failures or near-failures in the artificial reseeding of deteriorated ranges led to a careful scrutiny of the fundamental principles underlying success. Recognition that, of many available forage species, only a few were both productive and well adapted to the site and climatic conditions initiated adaptation tests with a large number of species on a series of variable sites. Need for information regarding when and how to reseed started tests of spring and fall planting and the effort to develop effective machinery and other methods of covering the seeds. A search for new or improved species or strains has also been undertaken by plant breeding, by collection of native forages, and by importation from other regions and other countries.

Useful Findings Made in Artificial Reseeding

Though as yet just well begun, research in artificial reseeding has succeeded in establishing several broad principles that serve as guides for reseeding operations. For the major favorable conditions in valley edges, foothills, and mountainous zones a good general program can be safely set up on established general knowledge of what to seed, where to seed, and when and how to seed. Effective means, though not fully complete, have also been found of making such information available to stockmen and organized agencies wishing to apply it. Progress, also, has been made in analyzing the problems to be solved, in testing the adaptability of species to the many ecological conditions in the Intermountain region together with collecting and testing the germination power of seeds of native forage species, and the development of appliances for gathering seeds and for planting and covering them.

What to Seed

Production of palatable forage and soil stabilization are desirable characteristics in any plan which may be considered for reseeding. However, the choice of forage plants for range reseeding depends largely upon their adaptability to particular sites. Since the artificial revegetation project was rejuvenated and broadened in 1935, certain species have been found suitable for reseeding on major problem areas and are being recommended for large-scale seeding. The species which have succeeded best in reseeding have been found to be palatable perennial grasses. Most of these species are bunchgrasses which spread by seed alone, though some spread also by rhizomes.

Most successful in high mountain ranges from the aspen to the subalpine zone are mountain brome (*Bromus carinatus*), smooth brome (*B. inermis*), slender wheatgrass (*Agropyron pauciflorum*), tall oatgrass (*Arrhenatherum elatius*) and some needlegrasses (*Stipa* spp.). Mountain brome is a fast-growing, prolific grass which thrives over

a wide range of soil and moisture conditions, from the mountain brush to the subalpine zone. Smooth brome, one of the most palatable of all grass species, establishes itself more slowly than some others but when once started, spreads by rhizomes and produces an abundance of forage. This species has also done well on low mountains and valley edges where favorable soil and moisture relations prevail. Slender wheatgrass grows on favorable sites from valley edges up to subalpine areas, with the best growth taking place in the aspen-fir zone. It is fairly drought-resistant. Tall oatgrass, a fast-growing species, has done well on the better sites from the sagebrush zone to the subalpine zone. Some native needlegrasses have succeeded from the mountain brush to the subalpine zones. On damp meadows or other sites with abundant moisture during the summer season timothy (Phleum pratense) and orchard grass (Dactylis glomerata) grow well, the latter being adapted to moist, shady places.

At intermediate elevations, corresponding roughly to the mountain brush zone, the following species have thrived: mountain brome, smooth brome, tall oatgrass, slender wheatgrass, crested wheatgrass (A. cristatum), bearded wheatgrass (A. subsecundum), and blue wild-rye (Elymus glaucus). The last three species establish themselves rapidly, though seeds of the last two are not commercially available. Crested wheatgrass, a long-lived, deep-rooted species, has established and reseeded itself from the drier sites of the sagebrush zone to the aspen belt with the best growth being made in upper sagebrush and in mountain brush areas. On drier sites, it establishes itself slowly but good stands have often been obtained when drilled in the driest years. Spring growth starts about 10 days before that of native species and an abundant seed crop is usually produced.

The lower foothills and valley edges which correspond to the sagebrush zone include problem areas such as burned and depleted sagebrush and abandoned lands. Since these areas usually receive double grazing use, once in spring and again in the fall, they are often referred to as the "bottleneck" of the livestock industry. Because soil moisture is usually low during the summer only the most drought-enduring grasses are adapted to these ranges, of which the most widely adapted is crested wheatgrass. Two native wheatgrasses, blue-bunch wheatgrass (A. spicatum) and beardless wheatgrass (A. inerme), have about the same range of adaptability as crested wheatgrass and are possibly more drought-resistant, though inferior in forage production, seed yield, and resistance to grazing. A small supply of seed in mixture is available commercially. Other adapted species include smooth brome, tall oatgrass, blue wild-rye, slender, bearded, and western wheatgrasses (A. smithii), and bulbous bluegrass (Poa bulbosa). The first five species, already discussed, are adapted to the more favorable sites of this zone. Western wheatgrass, a drought-resistant sod-former, is adapted for reseeding from the alkaline flats to the aspen zone. Because of slow germination and seedling development, sparse stands are obtained, which fill in only after 3 to 5 years. Bulbous bluegrass, an early growing,

tuft-forming grass, apparently has the ability successfully to compete with cheatgrass (Bromus tectorum) on the hot, dry sites of the sagebrush zone. Its growth is meager during the hot summer, but its early spring growth and its fall regrowth gives it value on sites which are too dry for the larger forage-producing species.

Present and future studies will undoubtedly extend the range of usefulness of many of the above species, and provide new adapted species which within the next few years will enlarge the list of species recommended at all sites.

Where to Seed

Research has shown that for the present, areas selected for reseeding should be those on which needed improvement in the plant cover cannot be obtained within reasonable time through natural revegetation, and where benefits attained will offset the costs of seeding. The quickest results and the greatest returns will be naturally obtained from areas having good soil and favorable moisture relations. For this reason the first plantings should be put on the most favorable sites. Economic studies show that reseeding favorable areas can be profitably done. During the past 3 years, justification for reseeding has been augmented by reductions in seed costs of one-half or more for most species. With the devising of less expensive methods of planting, reseeding may be extended to less productive lands. Even though costs appeared to be excessive, certain critical areas closely related to the welfare of dependent communities have demanded immediate attention, in order to control erosion and regulate stream flow. Reseeding on these watershed areas, after terrace trenching, has been successful and has fulfilled its purpose. Although immediate forage production will not repay the cost, the needs of dependent communities have probably justified the work.

Of many methods of seedbed preparation tried, at least one has been found that is suitable for each site. Except on better lands, most methods of seedbed preparation are too expensive to be economically profitable. Any method of treatment which leaves litter on the surface is an aid in seedling establishment. This is important as seedings can be made in trashy material without further expense. Thick stands of sagebrush (Artemisia spp.), rabbitbrush (Chrysothamnus spp.), and cheatgrass have hindered, and in some places prevented, successful establishment of reseeded species. Unless reseeding on such areas is preceded by some method of reducing the competition the results may not justify the cost. In Nevada, herbage yield was 18 times, and in Utah 20 times, greater where heavy sagebrush had been burned than on a similar unburned site. Some disadvantages of burning are that it temporarily lowers watershed values and destroys much litter.

When and How to Seed

Because a dependable moisture supply is necessary for germination and seedling establishment, it is safer to sow seed just before the fall rainy period, or as soon as hot, dry weather is over. Some of the best results have also been obtained by late fall seeding with germination and seedling establishment taking place the following spring. Spring planting is usually uncertain because ordinarily after spring seeding not enough moisture remains to permit a development of seedlings that will carry them through dry, hot weather of summer.

In general, experiments show that seed should be covered. Occasionally good stands have been obtained by broadcasting on the snow or on bare ground with no covering, but these successes have been exceptions and the practice is not safe. Results with season and depth of planting studies have been found to vary with season, species, soil, and moisture conditions. Ordinarily, in fall seedings one-fourth to one-half inch in best for small seeds and one-half inch to one and one-half inches for large seeds. Considerable success has been obtained by adjusting a disk drill to cut to depths of 1 or 2 inches. The seed is covered to a shallow depth by dirt that rolls back into the furrow.

Large-scale plantings show that seeding machinery should be suitable to the physical nature of the site. Where conditions permit, drilling has been found to be the most practical method of seeding because it provides more complete and uniform covering of seed. To facilitate drilling on steep slopes, a special sidehill drill has been developed which will successfully operate on slopes up to 70 percent. Considerably less seed is required to secure a stand by drilling than by other methods. Where drilling is not practicable, other ways of covering seed such as contour plow furrows, disking, harrowing, railing, brushdragging, or trampling may be used. For the last three methods to be successful, the soil should be fairly loose to permit soil to cover the seed. Power-drawn machinery is proving practical on large-scale reseeding projects. Wheatland plows or Killifer disks are showing exceptional promise.

Carrying Information to the Public

Reseeding results have been made available to the public through numerous talks on reseeding, through hundreds of letters answering queries of interested stockmen, by holding field days in cooperation with state extension departments, and through publications. "Reseeding Range Lands of the Intermountain Region", USDA Farmers' Bulletin 1823, redefines the possibilities of reseeding and presents the status of knowledge on reseeding in 1939. In addition five minor publications dealing with the following phases of revegetation work have been published: (1) Revegetation practices and results (general); (2) reseeding trials on oakbrush ranges; (3) the place of bulbous bluegrass on Intermountain ranges; (4) drilling grass on steep slopes; and (5) reseeding instructions for forest supervisors.

Planning the Program

To point out and analyze the principal reseeding problems and to serve as a basis for planning the broad phases of a research program, a comprehensive project analysis and working plan has been prepared. As needs for specific studies have been determined, more than two hundred study plans have been written as guides for specific problems. These plans include such information as purpose, state of existing knowledge; statistical design, experimental treatments, methods of procedure, method of analysis, work and report schedules, and costs.

Search for Adaptable Species and Testing Their Seeds

To increase the number of species available, a seed acquisition and collection program has provided seed of 337 species for testing in the region. Of these 115 have done well in intensive nursery studies and 84 are being tested under actual range conditions. Plant breeding has already contributed 19 strains of several species now being tested under various range conditions. Natural variations within many native species are being observed at 10 different sites to determine whether differences are due to site or to inherent genetic characteristics.

The following procedure has been developed for testing the adaptability and usefulness of newly acquired species: (1) All species are studied in small row plots where plant competition is controlled. (2) Species which make satisfactory showings in rows are tested on larger plots under actual range conditions. (3) Species which do well in range plot tests are recommended for demonstration and large-scale plantings.

Some species are adapted for range reseeding but because seed is not commercially available they are not available for general use. To overcome this a cooperative seed production program has been initiated in which seed of promising species is furnished to selected farmers and stockmen who produce the seed on a share basis.

In the case of many species that have refractory seed, special methods have been developed to ascertain the actual germinations, which may involve various scarification and cold treatments. It has been found necessary to pretreat seed of some species in order to obtain satisfactory field stands. To do this a laboratory technique has been developed and practical methods for treating seed for field planting will be designed.

Developing Machinery

To stimulate large-scale planting operations on an experimental plot basis, small 1-hp. garden tractors have been equipped with drill disk seeders and cultivator diggers. The same tractors have been so adjusted that various weeding implements can be attached to cultivate nurseries with a minimum of time and effort. For larger experimental plots, the 1-horse, 5-disk drill has been successfully used. Either the drill or the garden tractor is easily transported in a ½-ton truck or panel delivery sedan. Hand machines and equipment have been devised for the collection and cleaning of seed of native species not now on the market.

Needs and Plans

Continued research is needed to make operative much of the information now gathered and to establish artificial revegetation as an effective method for rehabilitating the ranges. Studies of depth and date of planting, the relation of site to rate of seeding and prospective stand density, and the rooting of cuttings by hormone treatment all need to be extended to field practice.

A study is well begun on the distribution of native species with a view of artificially extending the ranges of valuable plants now occupying restricted areas. Acquisition of promising introduced species from all possible sources should be continued. Field tests of newly acquired plants, additional studies of questionable species, relation of source of seed to success in artificial revegetation, and the development of economical methods of seeding sagebrush and cheatgrass areas are problems to be solved.

The program to increase seed supply should be continued and enlarged in cooperation with private operators throughout the region, in order that more native species will be rapidly made available for large-scale reseeding. If possible, devices should be developed for the more efficient collecting and cleaning of seed of native range plants.

Finally, the ability of promising species to withstand various seasons and intensities of grazing needs to be tested, perhaps in cooperation with one of the grazing projects.

HISTORICAL SUMMARY OF RESEARCH AT THE GREAT BASIN BRANCH STATION

The Great Basin Branch Station is the oldest range experiment station in the United States. It has now reached a point in its development where a number of lines of work have been brought to completion and it seems desirable to reorient some phases of future effort. This historical resume of projects undertaken at the Great Basin Branch Station stresses the significance of development in thought rather than specific findings, which have been given in earlier annual reports. A summary of recent accomplishments is contained in an earlier section of this report.

Perhaps the principal factor in the establishment of "The Utah Experiment Station" as it was called in the early days, was the need for control of the disastrous floods which were damaging farms and communities at the mouths of canyons in the Intermountain region. Evidence had been accumulated to show that many of these floods were the result of range abuse, and so among the studies which were immediately undertaken in 1912 was the establishment of a pair of 10-acre experimental watersheds in the head of Ephraim Canyon. At the same time a number of other projects were also undertaken: control of erosion, grazing management to secure natural revegetation of depleted range, artificial revegetation, control of poisonous plants, effects of grazing on aspen reproduction, climatic characteristics of the major vegetal zones, and the identification, distribution, and economic importance of range plants.

Certain forest management problems were undertaken at the Station, apparently under Administration leadership. These included studies in methods of management of aspen and in forestation of coniferous species. By 1920, because of the lessened economic importance of aspen and because it was desired to concentrate forest management studies in the more important timber types of Idaho, silvicultural work at the Great Basin Station was discontinued. The results of environmental studies and forest planting trials are incorporated in Technical Bulletin No. 256 under the title "Suitability of Brush Lands in the Intermountain Region for the Growth of Natural or Planted Western Yellow Pine Forests."

The erosion studies led to the publication in 1918 of a preliminary report giving the results of the watershed trials and of experiments in erosion control. It is interesting to note that the technique of terracing mountain watersheds which has developed intensively in late years in the Intermountain region, was foreshadowed as early as 1917 in this work at the Great Basin Station. In 1931 data from the watershed study were reported in "A Study of the Influence of Herbaceous Plant Cover on Surface Run-Off and Soil Erosion in Relation to Grazing on the Wasatch Plateau in Utah." (U. S. Dept. Agr. Tech. Bul. No. 220). The major findings of this study are two:

(1) striking differences in the characteristics of run-off and erosion at different seasons; and (2) a definite, inverse relationship between the presence of vegetation--both amount and quality--and the amount of surface run-off and erosion. Run-off from summer storms, which is only about 5 percent of the average total run-off, causes about 85 percent of the erosion from a depleted cover type. Melting snow, which produces a far greater amount of run-off and which is practically the sole source of underground water supply, produces relatively little erosion. After the vegetation was allowed to increase about 2½ times in density, more than half the erosion was stopped. Incidental studies have shown that eroded soils tend to be deficient in nutrients for plant development as well as in the essential textural qualitites necessary for establishment of good vegetal cover, and that plants growing on eroded soils require markedly more water than plants growing on noneroded soils. As a result of this complex of deficiencies, plant growth is handicapped on eroded soils.

Beginning in 1934 a unique element of experimental design was incorporated into the watershed study by reversing the grazing treatments. In terms of erosion and run-off, response to extreme utilization was almost immediate. In the same year experimental areas were established in two cover types at lower elevations, equipped with catchment devices to measure erosion and run-off within a range of grazing treatments. A differential as a result of treatment has already become evident.

In the science of range management, perhaps the most significant contribution yet made is the application of the concept of ecological succession to grazing types. This contribution and a description of the successional process in the Hudsonian Life Zone of the Wasatch Plateau were made early in the history of the Great Basin Station. Practical application, through the adoption of "plant indicators", was widespread. For many years the Station attempted to follow this study up by a study of the causes, physiological and biological, of plant succession; but although the project was approved, funds were never appropriated, and so the study of successional causes has remained pretty much at a standstill since about 1919.

The study of effects of grazing upon aspen reproduction, which was begun early in the Station's history was soon carried to completion. Inasmuch as the importance of aspen as a timber resource has changed radically since that time, this study no longer has the significance that it once had. By example, the study serves to point out, however, the necessity for orientation of research effort into close alignment with permanent needs.

The poisonous plant eradication project, which was concerned mostly with methods of eradication of tall larkspur, was also brought to completion in a few years. A suitable method of eradication was developed which apparently promised to be cheaper and fully as effective as the method of grubbing. The results, however, were not tested on a large scale and so the experiments never received verification.

A study of plant vigor as affected by clipping was begun in 1916. The essential finding of this study was that very early and very close cropping were extremely harmful. Three small pastures were established in 1922 in expectation of testing these results under grazing conditions. However, due to a number of technical difficulties the results from these pastures were inconclusive. Later, studies of carbohydrate storage, which have been described elsewhere in this report, indicated the manner in which physiological processes of plants are affected by grazing. Most of the past work on plant vigor has now been completed and further developments will probably be undertaken by the Utilization Standards project. A utilization study was begun in 1923 with establishment of a pasture in which the grazing of cattle was controlled by the use of temporary hurdle plots. Due to technical difficulties this study, too, proved inconclusive.

The earliest artificial revegetation studies were not the first attempts at reseeding depleted range. The need for artificial reseeding was recognized as early as 1905, but the earliest attempts were mostly failures. It became apparent that to attain success, research in artificial revegetation was essential. Artificial revegetation experiments were largely confined to the higher elevations of the forest range during the first half of the Station's existence. After about 1925, effort was concentrated upon the lower mountain country in the oakbrush zone. In 1935 artificial revegetation work at the Great Basin, which, while productive up to a certain point, had tended to become haphazard because of the pressure of other work, was reorganized and consolidated into the Artificial Revegetation project of the Intermountain Station.

The climatic characteristics of the three main vegetal zones on the west front of the Wasatch Plateau have been studied almost since the inception of experimental work at the Station. In early days the instrumental study was supplemented by phytometers. One of the major generalizations from this study was that evaporation, or the complex of factors which go to produce evaporation, is one of the controlling factors in the distribution of plant associations. A recent summarization of 20 years of instrumental records is to be found in "Climate of the West Front of the Wasatch Plateau in Central Utah" (Mo. Weather Rev. 65: 291-301, 1937), and the effects of climatic factors on plant phenology in "Weather and Plant Development Data as Determinants of Grazing Periods on Mountain Range" (USDA Tech. Bul. 686).

As a supplement to the major undertakings at the Great Basin Station, an area was selected about 1920 on the Dixie National Forest to conduct a grazing trial on browse range. The trial, conducted in part by Station personnel and in part by Administration, was reported in 1929 as "The Utilization of Browse Forage as Summer Range for Cattle in Southwestern Utah." (USDA Dept. Circ. 62, 1929). Another cooperative grazing study away from the Station was undertaken in 1923 at the U. S. Sheep Experiment Station near Dubois, Idaho. In July 1930, as a result of the McSweeney-McNary Act, the Intermountain Forest and Range Experiment Station was formed with headquarters at Ogden and the Great Basin Station become a branch station.

In brief and necessarily incomplete form, this is the history of the Great Basin Branch Station.

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While there has been a great deal of fine work done at the Great Basin and while it may justly take credit for a number of basic ideas which have proved fertile in the advancement of research, there have been at the same time a number of failures, some of which, as we look back on them now, might have been prevented. It is from these that we should learn: every good is likely to come from a frank evaluation of past mistakes. The following four generalizations from the hard teachings of experience, while they may be considered far outside the scope of positive research and do not often appear in formal publication, are none the less valuable as results. They may well be pondered prior to launching new research effort.

1. It is necessary to be sure that problems undertaken in research are of permanent significance and not just the results of transitory interest. Thoughtful planning, with a comprehensive objective in mind, is essential.

2. It is necessary to be realistic as to the amount of work that can be accomplished. Bitter experience has proved that carrying too heavy field schedules, while it may result in the accumulation of a mass of data with a false sense of accomplishment, also results in inability to keep compilation up to date. As a result, errors accumulate and the constructive viewpoint becomes submerged in a hurried and eventually meaningless routine.

3. It is very desirable before undertaking a study to have some assurance, as from preliminary tests, that the differences expected are actually measurable by the techniques at hand. Too frequently the end of an experiment has been reached only to discover in analysis of the data that the measuring devices were too crude to describe the reactions.

4. Effort should be so planned that research technicians devote as much time to actual research work as possible. It has frequently been considered necessary to divert research effort in order to accomlish pressing administrative duties. While yielding to expediency may be condoned in some measure, too often it has resulted in permanent injury to the quality of research. //

At the present time four major projects are in operation, and their general attack and broad objectives are as follows:

1. Forest and Range Influences: Studies of the influence of herbaceous range cover and its use on stream flow, water losses, and soil stability will continue to occupy an important place in the Great Basin Branch Station program with a view toward determining the maximum permissible use of the range resource consistent with safe watershed management. Earlier work definitely established qualitative relationships between changes in the plant and soil mantle and stream flow and erosion phenomena. There is need for more intensive study of the numerous factors involved in stream flow, evapo-transpiration losses, and soil erosion in order to determine quantitative relationships between these phenomena and the contributing factors. Facilities are now available for these studies and if personnel can be provided much progress should be achieved in this field within the next few years.

2. Artificial Revegetation: Conceived as applicable where natural processes of revegetation are not economically adequate, artificial revegetation aims to restore the best possible plant cover on depleted range in order to improve the watershed resource and to induce maximum productivity in forage. The aim of research is to find ways and means of doing this. Accordingly, at the Great Basin Branch Station, a systematic series of species adaptability trials and tests of methods of reseeding under a wide variety of site conditions are now under way or in process of establishment. The Great Basin has many natural advantages as a center for artificial revegetation research, as well as for ecological research generally, because it gives access to an enormous range of sites and climates within a short travel radius, and, moreover, is in the midst of a critical watershed and range area.

3. Utilization Standards: The purpose of this project is to determine levels of range forage utilization such that the productivity of various types of range may be sustained indefinitely. A working plan is in process of completion, in which studies center on the physiological effects upon range plants of cropping by livestock.

4. Management of Summer Ranges: The maintenance of productive ranges and watersheds and the rehabilitation of depleted ranges and watersheds by natural means, manipulating the reactions of vegetation to environment, is the ultimate objective in management of summer ranges. The research problem is essentially one of determining the ecological relationships of vegetation so as to devise techniques of management which will work purposefully with the processes of rehabilitation and maintenance as found in nature. Such ecological relationships are not only interrelationships between plant and plant, but are also the relationships between vegetation and climatic, edaphic, and biotic influences. The project is thus one of

very wide scope. At present the work is divided into three major processes: (a) continuation of climatic records; (b) continuation of studies of plant development and forage yield, especially as affected by climate; and (c) completion of the analysis of accumulated natural revegetation data and prosecution of an ecological survey with the three-fold purpose of supplementing this analysis by filling out the successional picture, of laying the groundwork for ascertaining the successional processes in the aspen-fir and oakbrush zones, and of segregating important management problems of greatest urgency.

FOREST ECONOMICS

RANGE ECONOMICS

The work in forest and range economics approaches the management problems of western "wild" lands from the economic and social aspects and the objective of this work is to evaluate the various alternatives in the use and management of these lands so that they may make a maximum contribution to economic and social welfare and stability.

The major aspects of work in this field in the Intermountain Region are: (1) What type and size of livestock operation should use the grazing resources of the public lands? (2) Where a decision is necessary between livestock grazing and other uses such as big game animals or recreation, what are the relative values involved? (3) What are the economic and social values involved in conservation questions where choice is necessary between grazing and watershed or other values? (4) An appraisal of the use relationships of different seasonal ranges and other feed resources, particularly where one seasonal range or feed resource is deficient or especially in need of conservation adjustments. (5) The relation of privately owned grazing land values and capitalization to the use and management of lands in public ownership. (6) The relation of taxation on privately owned grazing land and feed crop land to the management and highest use of the public lands.

Economic and Social Aspects of the Use of Grazing Lands in Public Ownership

The major choice in the use of forest and range lands for the grazing of domestic livestock is between the livestock enterprises of general farms in the irrigated valleys and the use of this grazing resource by range livestock operations which are of sufficient size to be efficient specialized livestock operations. The efficient sized range sheep operation in much of the Intermountain region is determined largely by the fact that a band of sheep on the winter range needs to be about 2,500 head for a low-cost winter operation. On the other hand, the farm flock of sheep does not need to be of any particular size from an efficiency standpoint, especially if they are wintered on farm feeds. About the only qualifying factor is that the farm flock should be large enough to make a contribution of some importance to the farm family income.

Although certain of the Utah forests have a large number of farm flock sheep and farm herd beef cattle permits, these smaller permits do not as a rule absorb more than one-third of the total grazing use on these forests. These small grazing permits do make important contributions to the income and family living needs of large numbers of small farms, and where choice is necessary between

the small permits and the large permits, the question resolves itself into a choice between the economic welfare of a rather large number of farm families and the financial solvency of the larger commercial range livestock operations. However, it is probable that extremely small permits are of questionable value to the owner.

Big Game vs. Livestock in the Use of Forest Summer Range

Due to the fact that competition has developed between big game and domestic livestock there are certain local situations on national forest range where it is necessary to determine the proper numbers of big game and domestic livestock. For the communities involved in this choice in the Intermountain region, there can be little question from the economic standpoint which kind of use is most desirable. The livestock using the national forest summer range contribute to the local income of these communities from six to twelve times as much as the financial contribution of big game animals due to hunter's expenditures. An economic analysis of communities adjacent to the Oak Creek and Fillmore divisions of the Fishlake National Forest shows that they have lost 10 to 15 percent of their agricultural income due to overpopulation of deer and the resulting competition by the deer and livestock on the forest summer range.

There are, of course, certain intangible values on the recreational side of a big game population which defy the use of the dollar sign, but it is fairly clear that a deer population of such a size that it does not compete with livestock will still yield these intangible social values.

The Differences between Upland Range Conservation Economics and Lowland Range Conservation Economics

The various experimental undertakings in the Great Plains and the lowland desert and semidesert country all indicate that a rate of stocking which maintains the range forage will also yield the highest incomes for range livestock operations over a period of time. In the level to rolling type of range country mentioned above where trampling of steep slopes is not a major conservation factor and where most of the range forage is accessible in about the same way, an overstocking of the range means that more of the available forage is used for maintenance and little is available to produce gain on market livestock. This means that the choice of proper numbers of livestock is principally a matter of good production economics. There appears to be a fundamental difference, however, in the rough upland country where certain areas of the more accessible range are used much more intensively than others. In this situation there is frequently no practical system of livestock management which will prevent the overuse of upland stream courses and open slopes. As a consequence, reduction of livestock numbers such as would protect the accessible areas does not result in any comparable gain in weights and quality of market livestock.

The result is that the choice does not rest on production economics but rather upon public policy and the conservation of lands which may also have other important uses such as watersheds and recreational values.

Economic Aspects of Seasonal Range Use Relationships

A high percentage of the summer range of the Intermountain region is found on the national forests. The spring-fall ranges are in private ownership or on grazing districts. The winter ranges are primarily the desert and semidesert ranges of the grazing districts. Most of the cattle in this region and sheep in Idaho are on harvested feeds during the winter months. Where the capacity of one of these interdependent seasonal ranges is deficient in relation to the capacity of other seasonal ranges, there is need for a policy which will conserve this range and encourage its improvement. Such a policy might well be the basing of commensurate property requirements upon the seasonal range which is deficient. If this is done it offers an incentive to private ownership to make better use and management of the deficient seasonal range. However, the theory of commensurate property is essentially a land use concept and adherence to such a procedure may create insurmountable difficulties for the smaller diversified permittees.

An evaluation of the balance between the capacity of various seasonal ranges will also point the way for both public and private land management policies, for adjustments in the opening and closing seasons, and for the use of various seasonal ranges where there is some margin in opening and closing use dates. This will require a reconciliation policy between different federal agencies that are managing interrelated range lands.

A Proper Valuation and Capital Value for Privately Owned Grazing Lands is Needed in the Management of Public Lands

There are definite economic limits as determined by western range studies for the values which can be supported by grazing land and feed crop land owned by commercial range operations. Western range land studies show that the capital value figures on range and feed crop lands are now 50 to 100 percent higher than can be supported under a reasonable livestock price situation. Furthermore, where these private lands are used in connection with public lands a part of the value of the low cost public land grazing has been capitalized into the private land values.

This situation of overvaluation is a strong incentive to the maintenance of too many livestock and the overuse of part of the privately owned lands and the public lands. The capitalization of the value of public lands into the valuation of privately owned lands introduces an element of fixity in the use of both the private and

public lands so that it becomes increasingly difficult to shift the use of public lands from grazing to other uses when higher values depend on the other uses. This situation can be improved by the adherence to sound economic policies on the part of both public and private credit aagencies.

An Approach to Adjustments in Grazing Land Taxation

Western ranch and land economics studies have developed an economic analysis which shows the value of an animal-month of feed on different qualities of range and the proper relationship of land taxation to the value of an animal month of range forage. The Forest Service, on the other hand, has developed information on grazing land capacity and range qualities to which the financial information can be applied in developing an economic approach to grazing land taxation. A study of present grazing land taxation shows that the present general level of grazing land taxation is 50 to 100 percent above the economic level and that within this present general level there is very little equalization of the tax load on ranches of different quality and carrying capacity. As a result, the present tax situation is an obstruction to good range land use. This is indicated by the fact that in many counties of the western states, 40 to 50 percent of all of the grazing land on the tax rolls is now held by the counties for tax sale or is subject to tax deed.

The necessary adjustment to correct this is, first, the establishment of grazing level of such lands at the economic level, and second, the equalization of grazing land taxes based upon quality of range, such equalization to be within the economic level.

Certain of our studies have been directed toward determining the basis for such an adjustment. The results to date indicate that a much lower tax, if based upon the economic considerations and grazing capacity information, will produce a higher tax return than will the present grazing land taxation system.

FOREST AND RANGE INFLUENCE INVESTIGATIONS

Forest and range influence investigations during the past year continued to seek and yield further light on the watershed management problems of the Intermountain Region through research at the Bannock Creek and Arrowrock substations in Idaho and at the Wasatch and Great Basin Branch Stations in Utah. Significant information was obtained on important phases of problems relating to stream flow, water utilization, and soil stability.

STREAM FLOW

The discharge characteristics of practically all Intermountain streams present a paradoxical problem. Normally low summer discharges contribute to serious water shortages while high discharges of the same streams in the spring following snow melt and for brief periods in the summer following torrential storms have created equally serious problems of water surpluses--chiefly in the form of destructive floods.

Regulation of stream flow has been accomplished in part on some streams through storage and transmountain diversions, but major physical improvements are not feasible on many streams, which lack reservoir sites. Even on streams where water conservation projects are feasible there is a continuous flood and sedimentation hazard. Watershed management provides the only means of regulation on some drainage basins and is essential on others for safeguarding downstream improvements.

In seeking a solution of watershed aspects of stream flow problems, research effort in the last year was focused primarily on the phenomena of overland flow and related infiltration characteristics. Both summer and spring discharge relationships were considered.

Summer peak-flow discharge from watersheds having a complete or satisfactory plant and soil mantle has been found to be due almost entirely to channel interception, with no indication of overland flow. The absence of overland flow on such areas is readily understandable when it is considered that infiltration rates of the surface soil have been found to range from 4.00 to 10.00 inches per hour, or more. These rates are in excess of the maximum intensity of summer storms thus far recorded. Because the magnitude of summer storms in this region generally is less than 2.00 inches per 24-hour period, the hazard of floods being generated from channel interception on watersheds in good condition is negligible.

Summer floods in this region have been found to occur only in tributaries on which portions of the watershed are either naturally barren and relatively impervious or where the infiltration rate has been reduced through deterioration of the plant and soil mantle by misuse. Analyses of hydrographs show that the volume of flood discharge generally is equivalent to only a fraction of an inch of precipitation and that the true flood source areas which contribute the overland flow usually do not exceed 10 percent of the drainage basin.

Infiltration rates of deteriorated range have been found to be as much as 90 percent less than on comparable range in good condition. Plot studies also show that excessively grazed areas yield as much as 150 times more surface run-off than ungrazed areas. These relationships clearly suggest that watershed improvement measures which will restore the normal infiltration rates on flood source areas will be materially effective in minimizing peak-flow discharges from currently deteriorated range watershed areas.

An earlier analysis of the flood situation on watersheds in Davis County, Utah showed true flood source conditions to be concentrated near the headwaters on areas totaling only about 6 percent of the entire drainage unit. These circumstances permitted the efficient application of remedial measures on the true flood source areas.

Flood source conditions are not so localized on many other hazardous watersheds in the region. More commonly, they occur extensively over the watershed in small spots. Improvement of such watersheds requires more extensive treatment than where the flood source conditions are localized. It appears that such watersheds are susceptible to effective treatment, however, since in many cases it is necessary to increase the infiltration rate only a fraction of an inch in order to prevent overland flow.

Infiltrometer tests have been found to be useful in the analysis of run-off characteristics but must be used with caution under conditions prevailing in this region. The area contributing overland flow on the Great Basin A-B watersheds, for example, has been found to increase with magnitude and intensity of storm. Records also show that infiltration varies during the season, ranging from relatively high values early in summer after snow has melted to low values in late summer, apparently due to changes in the surface soil. The calculation of average infiltration rates for such areas obviously requires the use of variable factors for both area and infiltration rate. Further research is needed to develop a method of deriving quantitative values for these relationships.

The daily peak-flow discharges of headwater tributaries of Ephraim Creek, Utah during the past spring have been determined to be related to a release of water from melting snow equivalent to storms of about 1.50 inches per 6-hour daily snow melt period. This rate is much lower than the infiltration rate of the surface soil mantle on most of the watershed which undoubtedly accounts for the negligible amount of overland flow that took place during the spring melt period.

Observations revealed considerable discharge from established gully channels, however, particularly where these were deep enough to intercept less pervious substrata. Infiltration tests show that the latter strata, when not penetrated by roots, become practically impervious after 6 hours of saturation, thus explaining the occurrence of subsurface flow into the channels. Infiltration rates were somewhat greater on substrata that were penetrated by root systems. Further research is needed to determine the extent to which the infiltration rates of impervious substrata can be increased by improving the plant cover and the comparative feasibility of retarding run-off of seepage flow by mechanical means. Until further information on these matters is obtained, contour-trenching on areas subject to extended periods of daily snow melt should be undertaken with caution and not until the surface and subsurface soil is tested for infiltration capacities.

The facilities for studying stream flow problems were materially improved during the year through the construction of gaging stations on 6 additional tributaries of Farmington Creek and on 6 tributaries in the headwaters of Ephraim Creek. Improvement in the approaches to the flumes on the Farmington Canyon tributaries is still underway as is also the extension of service trails to a network of climatological stations.

In 1941 it is proposed to devote most of the staff time to the operation of the 23 stream gaging stations in Utah and the 5 stations in Idaho. It is also planned to calibrate the new flumes in Farmington and Ephraim Creek and to devote as much time as possible to a further analysis of overland flow-infiltration relationships.

WATER UTILIZATION

Low summer stream flow stages and an ever-increasing demand for water have created a serious water conservation problem in this region. Major engineering works and improved water use practices in industry and agriculture are essential for solution of this problem, but watershed management also can contribute significantly by reducing peak-flow discharges, delaying the recession of streams following peak-flow stages and by reducing sedimentation.

Watershed improvement measures aimed at flood control and erosion prevention in this region are based primarily upon the restoration of the plant and soil mantle to a condition approaching normal. On range areas, improvement generally involves not only an increase in the density of plant cover but also an increase in the number of perennial herbs, such as the bunchgrasses. All vegetation is known to require water for growth. In view of the naturally limited water supply and the role of the plant cover in a watershed improvement program, it is essential to know whether an increase in the quantity and quality of the range cover will affect water yields through changes in evapo-transpiration, or consumptive use losses.

Five years of water yield records from the Bannock Creek lysimeters show that 4-foot profiles of homogeneous granitic soil with a partial plant cover retain about 50 percent of the annual precipitation. All yields occurred in the spring, 99 percent being seepage flow. This relationship of gross yield to evapo-transpiration loss closely approximates the difference between annual precipitation and run-off from the Boise River watershed.

Soil moisture measurements were made at the Arrowrock Substation last year on deteriorated annual weed range and comparable areas which had been improved by artificial reseeding as an indirect method of determining evapo-transpiration losses. The soil on all areas was at field capacity in the spring following the melting of snow. On the improved range, soil moisture reached the wilting coefficient about 10 days earlier than the deteriorated range. The moisture content dropped well below the wilting coefficient on all areas during the summer and remained there until fall storms began to recharge the soil. Both the improved and deteriorated range will require essentially similar quantities of precipitation to recharge the soil to field capacity. The study, therefore, suggests that improvement in the herbaceous range cover under these circumstances involved no increase in evapo-transpiration losses.

Soil moisture sampling pits were constructed at the Wasatch and Great Basin Branch Stations last year to facilitate studies of evapo-transpiration losses. Soil moisture is to be measured at 6-inch depths on two sides of each pit by means of tensiometer apparatus. One side of each pit is to be maintained in a bare condition, the other in normal cover.

During the coming year it is planned to continue water utilization studies in the Bannock Creek lysimeters and by means of paired soil moisture studies in the newly constructed pits and on field plots.

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EXPERIMENT STATION

SOIL STABILIZATION

The widespread occurrence of accelerated erosion with resulting soil productivity losses and sedimentation damage has created a third serious problem in this region involving the stabilization of soils on the watershed lands. As in other water problems, major engineering structures can contribute in part to the solution of erosion control but the most feasible approach in most problem areas is through the stabilization of soils in place by means of watershed management practices.

Research in this region and elsewhere has shown conclusively that destruction of the plant cover by misuse or abuse has been a major contributing factor in causing accelerated erosion. It is also known that other factors, including the climate, soil, and slope, play a part in erosion and that an understanding of all the factors is essential for planning control programs.

The vulnerability of mountain soils to accelerated erosion was further demonstrated during the past season in the results of soil profile studies on steep slopes. Numerous observations revealed that the angle of repose on slope of raw talus material is less than 80 percent. On areas where soil has developed from the same parent material slopes have been found to be as steep as 200 percent. Such slopes obviously are steeper than the normal angle of repose of fine-textured soil particles. It is equally clear that the only reason soil was able to develop on such slopes and to be held in place today in the face of gravitational forces is the presence of a plant cover. When this protective and integral part of the soil mantle is removed abruptly, as in the case of fire, soil creep must occur as a result of gravity.

This phenomenon was observed following a burn on granitic soil slopes in the Payette River drainage where slopes ranged up to 75 percent. Subsequent storms supplemented the gravitational forces, causing debris flows from all drainage channels of sufficient magnitude to block the North-South Highway in numerous places and to add much material to the North Fork which eventually will displace storage space in the Black Canyon Reservoir.

The staff assisted in the development of plans for a region-wide erosion problem area survey which is now being completed by Administration. This survey is aimed at focusing attention on areas needing soil stability work and to formulate action programs for correcting erosion problem areas. The staff also assisted in the conduct of the Ranger Training School through discussions and field demonstrations of erosion phenomena and erosion control methods.

Facilities for measuring silt discharges from experimental watersheds--other than the A-B and plot installations--are still lacking. It is proposed to develop a plan for overcoming this deficiency in 1941, through an adaptation of the silt-measuring methods used by the U. S. Geological Survey.

DRAINAGE BASIN COMMITTEE

The National Resources Planning Board Drainage Basin Committees for the Upper and Lower Colorado River, Bonneville Lake, Lahontan Lake, and Upper Snake River areas continued efforts last year toward integrating the projects of the numerous agencies involved into a coordinated program for solving important water problems. The major interest of these Committees thus far has been in the direction of large engineering works but through efforts of representatives of the Department, the importance of watershed protection and the social and economic aspects of all proposed projects are being given more and more consideration.

In view of the attention that has already been given to specific large-scale construction projects, the U. S. Department of Agriculture group for the Bonneville Lake, Lahontan Lake, and Colorado River drainage basins is urging that one of the 1941 meetings be devoted largely to consideration of investigational programs. It is proposed that three types of programs be considered, including: (1) Research effort such as the influences investigations of the Forest Service; (2) basic data compilations, such as the programs of the Weather Bureau and Geological Survey; and (3) survey activities leading to specific action programs such as the Flood Control Surveys of the War and Agricultural Departments and the projects investigations of the Bureau of Reclamation. The need for a fresh look at all types of investigational activities appears especially timely as a basis for developing sound plans for civil works following the current defense emergency.

FLOOD CONTROL SURVEYS

The Flood Control Act of June 1936 and the subsequent development of Field Coordinating Committees has provided an opportunity for the Forest Service, Soil Conservation Service, and Bureau of Agricultural Economics in the U. S. Department of Agriculture to participate in the solution of flood problems in the Intermountain region. Through Field Committees 17-A, -B, and -C, the Department is conducting either preliminary examinations or detailed surveys within the Colorado River-Great Basin, Upper Snake River, and Humboldt River drainage basins respectively, for the purpose of developing plans for remedial measures on the watershed lands of these areas in the interest of water flow retardation and soil erosion prevention.

FIELD COMMITTEE 17-A

A preliminary examination report upon the Great Salt Lake portion of the Great Basin drainage basin containing recommendations for a detailed survey on this area, was completed last year. Most of the basic data were also assembled for a preliminary examination report upon the Weber River; but the major effort has been concentrated on a detailed survey of the Sevier Lake watershed. Undertaken late in the summer, it has been possible for the survey crew to assemble most of the information needed for appraising past damages and to develop a tentative program of remedial measures. Much additional information is needed on the hydrological aspects of the survey, particularly on infiltration. Since the latter information cannot be obtained until this summer, it is expected that a report on this area cannot be completed until the fall of 1941.

The 1941 survey plans include completion of the Sevier Lake Survey, the revision and extension of the Great Salt Lake P.E. report so as to cover all of the flooding tributaries along the Wasatch Front, and the initiation of overall preliminary examination reports upon (a) the remainder of the Great Basin, and (b) the entire Upper Colorado River. After completing the Sevier Lake Survey it is proposed to initiate a detailed survey on the Wasatch Front. Completion of the overall P.E. reports on the Great Basin and the Upper Colorado will indicate the priority of additional detailed surveys.

COMMITTEE 17-B

The major effort of this committee involved the completion of a detailed survey report upon the Boise River. This report included a plan of remedial measures for the watershed lands which was supplementary to but coordinated with a multiple-purpose dam project proposed by the U. S. Corps of Engineers. The remedial measures recommended in the Department program included improved

range management practices and supplementary aids to recovery of the range cover such as artificial reseeding and contour furrowing, and small channel works such as check dams and revetments. It was estimated that this program would eliminate the hazard of minor floods and would reduce siltation by nearly 90 percent. The coordinated Army-Agriculture program would practically eliminate all flood hazard and would also provide needed water supply, power, and conservation benefits.

Most of the material was also gathered during the past year for a preliminary examination of the Weiser River. The Bureau of Reclamation is completing a detailed study of this area and the completion of the preliminary examination report is being suspended until further hydrological information can be made available by the Bureau of Reclamation.

During 1941 it is proposed to complete the P.E. report upon the Weiser and to initiate an advance study on hydrological aspects as a basis for developing plans for a detailed survey. It is also planned to complete a P.E. report upon the Upper Snake River above Idaho Falls.

COOPERATION WITH OTHER AGENCIES

The Intermountain Forest and Range Experiment Station is undertaking a number of studies in cooperation with other Federal agencies, state experiment stations, schools, and private individuals. Following is a list of projects and cooperating agencies:

Flood Control Surveys

BUREAU OF AGRICULTURAL ECONOMICS
SOIL CONSERVATION SERVICE

Preliminary examination and detailed surveys of run-off and waterflow retardation and soil erosion prevention for flood control purposes within Flood Control Field Coordinating Committees 17-A, -B, and -C.

Forest and Range Influences

U. S. WEATHER BUREAU
UTAH AGRICULTURAL EXPERIMENT STATION

Snow surveys conducted on the principal watersheds throughout the State of Utah.

DIVISION OF AGRICULTURAL ENGINEERING, SCS
BOISE RIVER WATER USERS

Survey of the snow cover on the headwaters and principal tributaries of the Boise River.

TOWN OF CENTERVILLE, UTAH
UTAH AGRICULTURAL EXPERIMENT STATION

Study of water-spreading to lengthen season of run-off for irrigation and log of ground water level fluctuation.

U. S. WEATHER BUREAU

Study of yearlong precipitation on experimental watershed, Wasatch Branch Station.

Range Economics

U. S. INDIAN SERVICE
FARM CREDIT ADMINISTRATION
NEVADA EXTENSION SERVICE
BUREAU OF AGRICULTURAL ECONOMICS
SOIL CONSERVATION SERVICE
GRAZING SERVICE - INTERIOR
NEVADA STATE EXPERIMENT STATION
U. S. FOREST SERVICE, REGION 4

Range reconnaissance on public domain and state lands to ascertain type and percent of cover, present use, and carrying capacity; also desirable policies for distribution of grazing privileges.

UTAH AGRICULTURAL EXPERIMENT STATION

Studies to determine the effect of different administrative policies in the allocation of grazing privileges.

Range Management

BUREAU OF ANIMAL INDUSTRY
U. S. SHEEP EXPERIMENT STATION

Spring-fall range management studies conducted at the U. S. Sheep Experiment Station near Dubois, Idaho.

JACKSON BROTHERS
J. R. ANDERSON
FOUNTAIN GREEN WOOLGROWER'S ASSOCIATION

Owners of sheep used in cooperative range management studies at the Desert Range Branch Station.

IDAHO AGRICULTURAL EXPERIMENT STATION

Study of chemical composition of range forages.

NEVADA STATE EXPERIMENT STATION

Comparative effects of open grazing and protected areas on forage production.

Artificial Reseeding

NEVADA STATE EXPERIMENT STATION

The artificial and natural reseeding of ranges in the State of Nevada.

BUREAU OF PLANT INDUSTRY
UTAH AGRICULTURAL EXPERIMENT STATION

Field, greenhouse, and laboratory investigations in plant breeding and reseeding of range forage plants.

SOIL CONSERVATION SERVICE
UTAH AGRICULTURAL EXPERIMENT STATION

Studies conducted at Benmore resettlement area on reseeding and grazing of revegetated abandoned dry-farm lands.

Forest and Range Biology

FISH AND WILDLIFE SERVICE - INTERIOR

Study of rodent population damage and control on range lands; also big game management.

FORREST MANAGEMENT

RS - INT
SILVICULTURE
Harvest Cuttings

January 27, 1941

HARVEST CUTTINGS (PONDEROSA PINE)

1. Field division: Forest management research.

2. Work project: Silviculture

3. Line project: Harvest cuttings.

4. Purpose: To determine the best methods of cutting ponderosa pine from the standpoints of reserve stand growth, natural regeneration, sustained yield, and watershed protection.

5. Review of past work: The principal line of work has been the measurement of actual results of various methods of cutting on permanent sample plots established for this purpose. Information on growth, mortality, reproduction, and logging damage has been derived and reported for a total of 23 plots on the Payette, Boise, and Salmon National Forests, some of them dating back to 1913. Similar data on an extensive scale were provided by a survey of five selectively cut areas in central Idaho. Experimental cuttings were made on the Boise Basin Experimental Forest in 1933. None has been made since. It is planned to further develop this experimental forest as a testing and demonstration area. Six periodic surveys (1935-40) of the experimental forest have been made to determine mortality from bark-beetle attack--a question of major importance in this type.

6. Accomplishments during past year: The barkbeetle survey of 1940 indicated a loss of 130 trees or 214,830 board feet of ponderosa pine on 2,182 acres of virgin pine type, equivalent to 0.8 percent of the total volume of the stand. This loss is more than twice as large as in 1939 and is nearly equal to the heaviest annual loss yet recorded, that of 1935.

7. Plans for next year: (1) Finish report on extensive cut-over area study. (2) Compile remeasurement data. (3) Check transects. (4) Remeasure 20 permanent sample plots. (5) Annual barkbeetle survey. (6) Plan and supervise experimental cuttings.

8. Date of completion: Indefinite.

9. Assignment: E. L. Mowat

RS - INT
SILVICULTURE
Stand Improvement

January 27, 1941

STAND IMPROVEMENT (PONDEROSA PINE)

1. Field division: Forest management research.

2. Work project: Silviculture.

3. Line project: Stand improvement.

4. Purpose: To evolve and test methods of stand improvement which are silviculturally and economically feasible in the ponderosa pine type.

5. Review of past work: (1) In 1934, 25 plots representing 5 degrees of thinning were established in sapling and pole stands. To date these have indicated that snow damage in the first 2 winters following treatment is heavy but not serious. (2) Demonstration areas established in 30-60-year-old stands have indicated that crop tree thinnings will yield up to 11 cords of fuel wood per acre, leaving a residual stand of over 100 trees including 40 to 50 choice well-spaced crop trees. (3) Pruning studies to date have indicated the type of tool suitable to use and the type of tree economical to prune. (4) Yearly removal of dead and dying trees on the experimental forest has supplied the village of Idaho City with a substantial portion of its fuelwood needs, and has served also as a sanitation and fire hazard reduction measure.

6. Accomplishments during past year: None, suspended.

7. Plans for next year: Completion of analyses on past studies. Report preparation. Remeasure 3 permanent sample plots.

8. Date of completion: Indefinite.

9. Assignment: E. L. Mowat and C. S. Schopmeyer.

RS - INT
SILVICULTURE
Silvics

January 27, 1941

SILVICS (PONDEROSA PINE)

1. Field division: Forest management research.

2. Work project: Silviculture.

3. Line project: Silvics (ponderosa pine).

4. Purpose: A major and a minor study are included. The major regeneration study aims to determine factors and conditions affecting natural reproduction through all stages, involving: (1) seed supply and distribution, (2) physical and biotic factors pertaining to germination and seedling establishment, and (3) factors pertaining to subsequent survival and growth. The minor forest phenology study aims to determine time of seasonal growth and other phenological events, to relate these to climatic data, and to use this information in other investigations and in forest management.

5. Review of past work: Regeneration factors: Cone crop records of 1,500 trees on permanent sample plots for past 7 years and seed trap studies have given useful data on seed production and distribution, showing adequate base supply in good seed years. During 1936-39 factors affecting germination, establishment, and growth were measured on a series of seeded plots in exclosures on north, south, and flat sites. Extensive transect studies (in addition to those on Mc plots) in 1935 and 1937 showed relations of soil, aspect, cover, etc. to establishment and first-year mortality of natural seedlings. Study in 1938-40 showed plant competition has little effect on germination, but greatly increases mortality and reduces size and vigor of seedlings.

   Phenology: On the Boise Basin Experimental Forest weekly measurements of current height and diameter growth of local tree species have been made through growing seasons of 1936-40; phenological notes and growth measurements have been made on key species of grasses, herbs, and shrubs.

6. Accomplishments during past year: Regeneration: Work on all phases continued; emphasis on competition and on seed production, quality, and dissemination (heavy seed crop in 1940); substantiated previous findings, showed little relation of seed quality to tree class, indicated effective heavy seeding distance of 100 feet locally. Phenology: current tree measurements continued.

7. Plans for next year: Regeneration: Seed supply measurements to be continued. Transects and competition plots to be checked. Compilation and analysis preparatory to major report. Phenology: Field work discontinued. Analyze data, correlate with weather records, and report when time permits.

8. Date of completion: Regeneration factors: Mostly by 1942, with minor phases on to 1944 or beyond. Phenology: indefinite.

9. Assignment: E. L. Mowat

RS - INT
REGENERATION

January 27, 1941

FIELD PLANTING AND SEEDING (PONDEROSA PINE)

1. Field division: Forest management research.

2. Work project: Regeneration.

3. Line project: Planting

4. Purpose: To determine (1) the factors of site and of source, size, age, and treatment of stock, and (2) the methods of planting and seeding responsible for good and poor survival and growth in order to develop (a) planting and seeding techniques and (b) criteria of site selection which will insure successful regeneration of burned-over and otherwise denuded timber lands in the Intermountain region.

5. Review of past work: (1) Exploratory studies in planting and seeding since 1934 have indicated the problems of gross stock, site, technique, and biology that need solution to assure satisfactory regeneration. Use of husky stock having good balance between top and root volume, with care in site preparation, including reduction in competition, have shown to advantage in planting; artificial protection of seeds and reduction of competition have proved distinctly beneficial in seeding. (2) Experimental nursery studies have indicated desirable seedbed protection, water schedule, and thinning practices. (3) Studies of root systems of planted and natural seedlings have pointed the need for a better understanding of root physiology in relation to pruning, lifting, and planting practices. (4) Seed studies have furnished a reliable seed maturity index, and indicated desirable collection and storage practices.

6. Accomplishments during past year: Tests of improved technique in direct seeding, and of seeding vs. planting, season and date of planting, root pruning, use of fertilizer, and site preparation were continued. In this unusually hot, dry season no method tried produced really satisfactory survival; even the treatments considered most favorable showed less advantage than expected, although some indication of their value was demonstrated. Germination tests of seed storage samples were continued.

7. Plans for next year: Make spring plantings in season and date tests. Initiate new tests of direct seeding and site preparation. Examine active plots per schedule. Prepare reports on past studies.

8. Date of completion: Indefinite.

9. Assignment: E. L. Mowat and C. S. Schopmeyer.

RANGE MANAGEMENT

RR - INT
MANAGEMENT
Utilization Standards

January 27, 1941

UTILIZATION STANDARDS FOR RANGE FORAGE PLANTS

1. Field division: Range research.

2. Work project: Grazing management.

3. Line project: Utilization standards: Determination of standards of satisfactory forage utilization on western ranges.

4. Purpose: This work, limited primarily to summer range types, is to determine: (1) The proper degree of use for range forage plants on various soil and site conditions; (2) suitable standards of judging degree of utilization; (3) the proper intensities of use for the various vegetational types; and (4) means of measuring degrees of utilization for the different classes of range forage.

5. Review of past work: Early work by Sampson (USDA Bull. 1405) and others led to the general acceptance by range men of 75 to 90 percent current utilization of the more palatable forage species at the close of the grazing season as proper degree of use for most summer range types. Forsling and Storm (USDA Circ. 62) established proper use within the above limits for the better forage species on browse (oakbrush) range, but found that degree of use needed to be modified somewhat to meet variations in composition of the plant cover if range deterioration was to be avoided. Surveys and actual use records showed these widely accepted values to be too high for plant types on unstable soils, typical of much of the central Idaho section. While these variations were noted and more conservative standards of range use advocated for some range types, methods of measuring utilization were not uniform and estimates accordingly were so widely variable that proper use has often not been realized. In line with the above objectives, work on this project was started at the Great Basin Station in 1938, at which time exploratory studies of the method of estimating utilization by stubble-height measurements, and the effect of different degrees of grazing individual plants upon their growth in subsequent years were initiated. In cooperation with the Region, a utilization standards handbook setting forth utilization standards for broad forage types was issued in 1939.

6. Accomplishments during past year: Four forests in the Region were visited and utilization checks made for a number of range types in view of the standards set forth in the Handbook, and for gathering additional information regarding local range types and range problems. Volume-height studies continued through the

1940 season indicate that this method may not be practical for range use on tall-growing bunchgrasses and weed species due to wide variation in volume distribution and difference in growth characteristics as influenced by seasonal conditions. Results obtained on the effects of grazing on subsequent yields indicate that the small plants tend to be grazed heavily year after year, and further that rate of recovery from the cumulative effect of treatment is a function of both species characteristics and site conditions.

Partly on the basis of these exploratory studies and indicated needs for the summer range lands of the West in general, a comprehensive problem and project analysis, with a detailed breakdown of study phases, has been prepared and submitted to Washington for approval.

7. Plans for next year: A publication covering material presented in the Range Utilization Handbook and other available information is proposed. If Washington Office approval is given, studies will be initiated on two or three subprojects as indicated in the problem and project analysis. In addition, it is planned to continue field studies primarily in methodology to determine suitable methods for (1) estimating utilization; (2) simulating grazing in controlled experiments; and (3) obtaining accurate forage inventories.

8. Date of completion: Indefinite.

9. Assignment: Ira Clark and George Stewart.

RR - INT
MANAGEMENT
Summer Ranges

January 27, 1941

CLIMATIC CHARACTERISTICS OF MOUNTAIN RANGES

1. Field division: Range research.

2. Work project: Grazing management.

3. Line project: Summer ranges: Methods of managing high summer ranges in the mountainous regions of the West.

4. Purpose: To maintain a complete and accurate record of climatic factors for correlation with observations in range, watershed, and timber management research.

5. Review of past work: Results of short-term studies prior to 1923 were published as USDA Bull. 1405. A climatic summary for four stations on the west front of the Wasatch Plateau for the 20-year period, 1914-34, was published in the Monthly Weather Review 65:291-301, 1937.

6. Accomplishments during past year: During the winter of 1939-40, with the help of State WPA labor, climatic records between 1935 and 1939, including summations of temperatures from thermograph charts, were compiled. In the field a complete check was made of the calibration of air and soil thermometers. The routine climatic observations were carried on, and were extended practically throughout the winter at the Transition and Canadian Zone stations. Soil thermometers were removed from the Transition and Hudsonian Zone stations, where it was not possible to observe them systematically, for use in other studies. At all stations a continuous graphic record is now made of soil temperatures at 6-inch depth, and at the Canadian Zone station soil thermometers at 6-, 12-, and 24-inch depths are read morning and evening during the growing season.

7. Plans for next year: Climatic observations will be continued and the instrumental checkup, which is being established as an annual practice, will be repeated. This project is being set up distinct from Plant Growth, Phenology, and Forage Production so as not to obscure its relationship to other studies or the importance of accuracy in instrumentation, which the earlier association may have tended to do. It is felt that since climatic information is basic, applying to all ecological studies, it should be obtained with the clear intent of serving all rather than any particular one, which is the basis on which the project was originally set up.

8. Date of completion: Indefinite.

9. Assignment: Lincoln Ellison.

RR - INT
MANAGEMENT
Summer Ranges

January 27, 1941

PLANT GROWTH, PHENOLOGY, AND FORAGE PRODUCTION

1. Field division: Range research.

2. Work project: Grazing management.

3. Line project: Summer ranges: Methods of managing high summer ranges in mountainous regions of the West.

4. Purpose: To determine relative influence of the various climatic factors on the rate of plant growth and amount of forage produced, the extent of variations in forage production which may be expected to occur, and adjustments of range management which may be necessary to conform with such variations.

5. Review of past work: Results of short-term studies prior to 1923 were published as USDA Bull. 1405. Technical Bulletin 686 "Weather and Plant Development Data as Determinants of Grazing Periods on Mountain Range" was published during 1939. This bulletin summarizes the relationships between climate, as altered by altitude, and the phenology of some range forage species on the west front of the Wasatch Plateau. Evidence is given of a relationship between snow melt in spring and subsequent phenological development which permits more accurate prediction of range readiness than does an arbitrary average date.

6. Accomplishments during past year: The working plan used in 1939 was revised in 1940 to secure greater simplicity and at the same time maintain maximum objectivity in measurements and phenological observations. A test was made of the regression method described in Tech. Bull. 686, using the data gathered during the four years 1936-39. In general the regression method failed to give quite as good results as the method of average dates, and a comparison of errors of estimate shows that there is not much to choose between the two methods. The reason for this is probably the large error inherent in our growth measurements and phenological observations.

7. Plans for next year: The plant growth data for 1940 will be analized to test the two methods of prediction further. In order to save labor, but to maintain continuity in the record, observations will be made at only three (rather than seven) stations, one in each major vegetal zone. All forage yield plots will be harvested as in the past.

8. Date of completion: Indefinite.

9. Assignment: Lincoln Ellison.

RR - INT
MANAGEMENT
Summer Ranges

January 27, 1941

SUCCESSIONAL STATUS OF VEGETATIONAL TYPES

1. Field division: Range research.

2. Work project: Grazing management.

3. Line project: Summer ranges: Methods of managing high summer ranges in the mountainous regions of the West.

4. Purpose: To determine the relation of the structure of plant communities now occupying extensive range areas to their potential structure under other systems of grazing management and the rate of successional change.

5. Review of past work: Results of early work on plant succession on the Wasatch Plateau have been reported in USDA Bulls. 791 (1919) and 1405 (1926). Studies on seed germination have been reported in Bot. Gaz. 98:243-269, 1936, and a report has been submitted for publication covering other phases of seeding habits of native range plants. Analysis of plot records, while generally inconclusive, received new impetus through finding a number of old records made between 1913 and 1923 which indicated positive changes in vegetal cover in the Hudsonian Life Zone from a first or first and second weed stage to a first grass stage in succession.

6. Accomplishments during past year: Old plots and quadrats were relocated in the field, photographed and mapped. Use records of the Manti National Forest were examined in detail, but proved to be less specific and exact than had been hoped. To date analysis of plot data indicates that changes in vegetation have been by no means uniform even within the same plant association. Some evidence has been accumulated to show that natural revegetation of badly eroded range depends upon accumulation of fresh topsoil and checking of run-off velocity, as a result of soil disturbance by rodents. Field work indicates that certain phases of the successional process as described by Sampson may require alteration, although the major features of his description check with current observation.

7. Plans for next year: By the end of F. Y. 1940 analysis of plot and quadrat data should be largely complete. Further ecological reconnaissance, a brief comparison of climatic factors on some grazed and protected plots, and probably some additional mapping of plots and quadrats will be necessary to round out the analysis. The ecological reconnaissance will also serve as the beginning of an extensive ecological and management problem survey.

No new work of major proportions will be undertaken until analysis of past work is complete enough to permit efficient planning. The work of plant collection and building up the Great Basin Station herbarium will be continued.

8. Date of completion: Indefinite.

9. Assignment: Geo. Stewart and Lincoln Ellison.

RR - INT
MANAGEMENT
Summer Ranges
Idaho

January 27, 1941

SUCCESSIONAL STATUS OF BUNCHGRASS-GRANITIC SOIL RANGE VEGETATIONAL TYPES

1. Field division: Range research.

2. Work project: Grazing management.

3. Line project: Summer ranges: Methods of managing high summer ranges in the mountainous regions of the West.

4. Purpose: To determine for bunch wheatgrass (Agropyron inerme and A. spicatum) on granitic soils (1) the vegetational condition of the plant communities now occupying extensive range areas and their potential condition under protection or modified grazing management, and (2) the rapidity with which changes take place.

5. Review of past work: Range inspections during the period 1929 to 1931 indicated that overgrazing is largely responsible for the serious erosion problem which exists on the Boise River watershed. A system of 100 meter quadrats and 105 major plots was established in connection with 11 enclosures, to study the natural revegetation of the watershed. Analyses of early records from these plots indicate that (1) natural plant cover, in good condition, provides adequate erosion control; (2) on much of the area, proper grazing will permit satisfactory recovery; but (3) largely because of lack of a seed source much of the seriously depleted foothill range will not recover without the aid of artificial revegetation. An examination in 1940 of plot data for the years 1931 and 1937, first and last years in which all of the plots were measured, indicates that protection from grazing is having a beneficial influence upon the vegetation. When the total densities of perennial grasses in protected plots is compared with the densities of the grazed plots paired with them, it was found that the protected plots have about maintained themselves throughout this extremely droughty period, but that the grazed plots have deteriorated more than 40 percent. Variance analysis shows these differences to be significant.

6. Accomplishments during past year: All plots were remeasured during the past field season and analysis of the first 10 years of the study is under way.

7. Plans for next year: During the current winter the results of the first 10 years of the study will be analyzed and if the results warrant it a short paper will be prepared. Some change in the work program for the study is needed at this time, and will be developed and put into effect following analysis of the data.

8. Date of completion: Indefinite.

9. Assignment: George Stewart and C. Allan Friedrich.

RR - INT
MANAGEMENT
Spring-Fall

January 27, 1941

METHODS OF MANAGING SAGEBRUSH-GRASS SPRING-FALL RANGES UNDER GRAZING USE

1. Field division: Range research.

2. Work project: Grazing management.

3. Line project: Spring-fall ranges: Methods of managing foothill spring-fall ranges in the mountainous regions of the West.

4. Purpose: To determine for sagebrush-grass spring-fall ranges the effect of different methods of grazing management, and different seasons and intensities of grazing upon individual plant species and upon sustained animal and forage production.

5. Review of past work: Investigations begun in 1923 indicated that continuous fall use, with key grasses being utilized about 60 percent, is not detrimental; spring grazing, in a manner similar to that used on adjacent ranges, when continued for a 15-year period results in almost complete extermination of more valuable forage species and the serious encroachment of big sagebrush; heavy grazing consistently year after year during a single period of the spring season will result in serious damage to some species; to obtain fullest sustained use of these ranges rotation management seems necessary.

   Removal of sagebrush on areas with a good grass understory permits the fullest benefits to accrue from management systems. Increases in forage production of 150 percent in 2 years resulted from removal of sagebrush by fire followed by proper grazing management.

6. Accomplishments during past year: From clipping studies carried on since 1934 it appears that removal of herbage may be most serious when perennial grasses and weeds are actively engaged in reproductive effort. Early removal followed by protection is not seriously detrimental. No difference is evident in rotation and rotation-deferred systems of management from the standpoint of the plant or animal. Proper grazing capacity of good sagebrush-grass range, under rotation management, appears to be from 1 to 1-1/3 sheep month per acre, fair range 1/2 to 3/4 sheep month, and poor range 1/4 to 1/2 sheep month per acre, one-half the use to be in the spring and one-half in the fall.

7. Plans for next year: Completion of compilation and report on phase completed in 1940. Preparation of plans for following period.

8. Date of completion: With modification needs to be continued 8 years.

9. Assignment: George Stewart and Joseph F. Pechanec.

RR - INT
MANAGEMENT
Spring-Fall

January 27, 1941

METHODS OF STUDYING SAGEBRUSH-GRASS SPRING-FALL RANGE VEGETATION

1. Field division: Range research.

2. Work project: Grazing management.

3. Line project: Spring-fall ranges: Methods of managing foothill spring-fall ranges in the mountainous regions of the West.

4. Purpose: To determine the most efficient methods of measuring native sagebrush-grass range vegetation, and to investigate the nature of variation in experimental material being used, methods of sampling, and types of experimental design that may increase the efficiency of range experimentation.

5. Review of past work: Testing adaptability of methods of studying native range vegetation was actively begun in 1932. The point-observation-plot method of determining plant density and the coordinate method of mapping shrubs were tested and found suitable. In a study of five different methods of determining percentage utilization the ocular-estimate methods in conjunction with clip-checks provided the most reliable measure. The weight estimate method was designed, tested, and found superior to estimates of density in indicating forage production.

   Covariance analyses, simple and multiple regression are extremely valuable tools for use in studying native range vegetation.

   Native range vegetation is three to seven times as variable as experimental material of agricultural experiments, and when the common types of sampling units are used strongly skewed frequency distributions are found. Personal error in rapid estimate methods is much less serious than the decreased intensity of sampling possible with tedious clipping methods.

   More intensive sampling, smaller experimental pastures, and better experimental design are necessary to insure more successful experimentation.

   In range surveys of sagebrush-grass range, using the weight estimate method, and 20 plots per section, the mean forage yield per section has a sampling error of 18 percent. Individual plant species have higher errors. The mean forage yield of blocks of 4 sections, where sampling was randomized by sections, had a sampling error of 10 percent.

6. Accomplishments during past year: No active field work was conducted on this study during 1940. Two papers were prepared, one published and the other about ready to be submitted.

7. Plans for next year: No active field work to be done during 1941. Data are to be compiled as completely as possible.

8. Date of completion: Indefinite.

9. Assignment: Joseph F. Pechanec and George Stewart.

RR - INT
MANAGEMENT
Spring-Fall

January 27, 1941

ECOLOGY OF THE SAGEBRUSH-GRASS SPRING-FALL RANGES

1. Field division: Range research.

2. Work project: Grazing management.

3. Line project: Spring-fall ranges: Methods of managing foothill spring-fall ranges in the mountainous regions of the West.

4. Purpose: To determine for the sagebrush-grass spring-fall ranges: The relation between environment and plant growth, with special attention to the relative influence of the various climatic factors on plant growth and herbage production; the structure of the plant community and the rapidity with which changes take place; and the relation of the present community to grazing use.

5. Review of past work: Effect of viscissitudes of climate on rate, amount, and character of plant growth is one of the most important factors in range management. Major forage species complete their growth during April, May, and June. Once in about every 3 years some growth may occur during summer and early fall. Flower stalk production is very uncertain, and the production of viable seed infrequent. Similar stages of plant development may, from year to year, vary 40 days.

   Severe droughts result in protracted damage to stands of perennial grasses that is not fully overcome in a period of 5 favorable years. Forage production, as indicated by density, may vary from 60 percent above to 65 percent below average in a 10-year period. Range recovery on badly depleted range areas is extremely slow, attributable to complete control of the area by big sagebrush (Artemisia tridentata).

6. Accomplishments during past year: Rather sharp decreases in the basal areas of Agropyron spicatum and Stipa comata occurred during a year which was extremely favorable for flower stalk and viable seed production.

7. Plans for next year: Seasonal yield, plant development, and yearly yield studies will be combined. Other phases will be continued as planned.

8. Date of completion: Indefinite.

9. Assignment: Joseph F. Pechanec.

RR - INT
MANAGEMENT
Spring-Fall

January 27, 1941

CHEMICAL COMPOSITION OF SAGEBRUSH-GRASS SPRING-FALL RANGE PLANTS

1. Field division: Range research.

2. Work project: Grazing management.

3. Line project: Spring-fall ranges: Methods of managing foothill spring-fall ranges in the mountainous regions of the West.

4. Purpose: To determine the chemical composition of forage species of the sagebrush-grass type and variations in composition induced by stage of maturity, viscissitudes of climate, and grazing management. This information is to be used as a guide in determining the most efficient use of forage species which grow in the sagebrush-grass type.

5. Review of past work: Informal cooperation begun in 1937 with the Idaho Agricultural Experiment Station in the study of chemical composition of range forages indicates that variations in the chemical content of herbage furnished by native forage species is large, and greater within than between species. Stage of plant growth is the most important single factor influencing the chemical composition of range forages.

   Forage furnished by perennial grasses and weeds is high in crude protein, phosphorus, and has a narrow calcium/phosphorus ratio during most of the spring grazing season. During the summer period the herbage looks as if it "cures well" but by the beginning of the fall grazing season it can be classed as poor forage since it then has a crude protein content of only 3.0 percent, a phosporus content of 0.04 percent, and a calcium/phosphorus ratio of 15 for grasses and 40 for weeds. A sheep could not eat sufficient of such herbage to satisfy maintenance requirements for protein and phosphorus. At this time shrub herbage is twice as rich in crude protein, and three times as rich in phosphorus as that furnished by grasses and weeds.

6. Accomplishments during past year: Routine collections of range forages were made and submitted to the Idaho Agricultural Experiment Station for analysis.

7. Plans for next year: The study will be continued as planned.

8. Date of completion: About 1950.

9. Assignment: George Stewart and Joseph F. Pechanec.

RR - INT
MANAGEMENT
Winter Ranges

January 27, 1941

UTILIZATION, SEASONAL USE, AND ANNUAL RESPONSE

1. Field division: Range research.

2. Work project: Grazing management.

3. Line project: Winter ranges: Utilization, season, and intensity of grazing.

4. Purpose: To determine (1) degree of utilization that will insure rehabilitation of desert ranges and insure their maintenance in perpetuity; (2) relative influence of intensity and season of use on plant cover and forage production; and (3) influence of degree of forage utilization on condition of sheep as reflected in the weight of animals and animal products such as wool, lamb crop, etc.

5. Review of past work: Eighteen 320-acre pastures stocked from 1935-1937 indicated proper intensity of grazing at the desert experimental range to be approximately 0.04 forage-acre per head per month for sheep which required approximately $2\frac{1}{2}$ acres a head per month. This was based on data obtained by the square-foot-density method. Improvement in the plant cover under proper grazing indicates the rate of stocking can now be increased 30 to 40 percent. Plant vigor and herbage yields have increased fully twice as much as has plant density. Consequently, density alone fails to indicate the amount of forage available. Forage weights can be extimated with considerable accuracy and provide a more concrete basis for stocking. The pastures are partly paralleled by four herd allotments.

Sheep weights are markedly influenced by range conditions and intensity of grazing. Average change in weight of sheep under heavy, moderate, and light use, during a 40-day grazing period in the winter of 1937-38, was -3.45, ÷3.76, and ÷5.98 pounds respectively. Sheep grazed on pastures in the fall during 1938-39 showed changes in body weight of -3.20, ÷1.81, and ÷1.50 pounds; those grazed during the winter -1.72, ÷3.50, and ÷1.76; and those grazed in the spring ÷2.50, ÷6.80, and ÷4.15 pounds per ewe for heavy, moderate, and light grazing respectively.

Two flocks of sheep alternate from year to year between the moderately grazed experimental area and the heavily grazed open range. The flock that winters on the experimental area has produced an average 0.93 pound more wool per animal for the past 4 years, a 3 to 8 percent greater lamb crop, and death

losses from malnutrition are 5 percent less. Also, the sheep on moderately grazed areas are wintered in 10 to 12 pounds better flesh, without the aid of supplemental feed, than are those on the open range. Net profit for the herd wintered on the experimental range in 1936-37 was 58 cents per head greater than for the herd wintered under outside conditions. In 1937-1938 income for the increased wool alone was $825 greater in favor of the herd with ample forage.

Three years after establishment of managed grazing, forage production under moderate use more than doubled those on similar heavily grazed areas. Plant vigor rapidly increased, 1,000 plants produced 5 to 10 times greater quantity of forage than did a similar number of plants on the adjacent heavily grazed ranges, and the better forage plants such as Indian ricegrass, black sage, and winterfat showed the greatest and most rapid recovery.

6. Accomplishments during the past year: Moderately grazed ranges withstand drought much more effectively than heavily grazed ones. Forage production on a moderately grazed paddock in 1940, the driest growing season since the establishment of the Desert Range Branch, was only 28 percent less than the production of the same paddock in 1938 when precipitation was 55 percent above the 7-year average. On an adjacent heavily grazed paddock forage reduction was 61 percent. Ranges moderately grazed recover as rapidly and can be maintained in approximately the same productive state as ranges under total protection.

7. Plans for next year: Continue studies on influence of degree of use on condition of sheep and range forage production. Complete analysis of past data.

8. Date of completion: Indefinite.

9. Assignment: George Stewart and Selar S. Hutchings.

RR - INT
MANAGEMENT
Winter Ranges

January 27, 1941

SUCCESSIONAL STUDIES IN RANGE PLANT TYPES

1. Field division: Range research.

2. Work project: Grazing management.

3. Line project: Winter ranges: Successional studies in range plant types.

4. Purpose: To determine (1) the general condition of the plant cover on the winter ranges; (2) the degree and rapidity of recovery and natural revegetation on properly managed and totally protected ranges; (3) the role of seedling establishment and increased plant vigor of the better forage plants in range recovery.

5. Review of past work: General surveys of the winter ranges in western Utah and Nevada indicated that the plant cover had been reduced 34 percent from the pristine conditions and the volume of forage produced had decreased 62 percent as a result of improper seasonal use and heavy grazing. Areas totally protected from grazing from 2 to 7 years show remarkable increase in plant cover, forage production, plant vigor, and soil stabilization. Forage production on these areas is now 1.5 to 3.5 times greater than on the adjacent heavily grazed range. The first and most noticeable increase resulted from increased plant vigor. Indian ricegrass (Oryzopsis hymenoides) produces 3 to 8 times more forage per plant on the protected enclosure than on areas heavily grazed; black sage (Artemisia nova) and winterfat (Eurotia lanata) produce approximately 3 and 5 times more herbage per plant on the protected areas. On protected and properly grazed ranges Russian-thistle (Salsola pestifer), rabbitbrush (Chrysothamnus stenophyllus), and many other inferior forage plants, abundant on overgrazed ranges, have almost disappeared. Seedling production is almost equal on heavily grazed and protected areas, but seedling survival is 3 to 8 times greater under protection.

On four enclosures fenced in 1932, ricegrass had by 1938 increased 2.0 to 5.5 times, galleta grass (Hilaria jamesii) 2.7 times, and winterfat 1.8 times. Shadscale (Atriplex confertifolia) showed little change but rabbitbrush, an inferior forage and prolific seeder, increased 1.5 times on the open heavily grazed range but decreased 33 percent under protection.

Four additional enclosures established in 1937 in Nevada showed remarkable recovery by 1939. At Ely, Nevada, winterfat, which constitutes about 75 percent of the vegetation, increased approximately 44 percent, sagebrush (Artemisia tridentata)

increased approximately 42 percent, and grasses originally scarce are now 8 times more abundant. The protected area is now producing almost twice as many pounds of forage as the adjacent grazed plot. On an enclosure at Yerington, Nevada, winterfat increased 65 percent on the grazed plot. The weed desnity increased more than 10 times; enough to result in a total increase in density on the grazed area in excess of that obtained under protection. At Wellington, Nevada, black sage on the protected area showed a net increase of approximately 32 percent. This highly palatable species constituted more than 90 percent of the vegetation.

6. Accomplishments during past year: Drought during the past summer drastically influenced plant densities and herbage yields on both protected and grazed areas. Shadscale showed the greatest decrease in density amounting to 62 percent under protection and 60 percent on open range. Curlygrass, primarily dependent on summer precipitation, made very little growth. This species decreased more than 50 percent on both grazed and protected areas. Density of ricegrass on the open, heavily grazed area in 1940 was less than that recorded for the same area in 1932, but on the protected enclosures it was more than twice as abundant. Total density decline was approximately 30 percent on the protected areas and 45 percent on heavily grazed ranges. Total herbage yield is 75 to 100 percent greater on the protected areas.

7. Plans for next year: The 27 enclosures established in Nevada in 1937 and 1939 in cooperation with the University of Nevada will be remapped and estimated during the coming season. Also a number of enclosures in western Utah will be estimated again. The data will be compiled and a report and paper submitted.

8. Date of completion: Indefinite.

9. Assignment: Selar S. Hutchings and George Stewart.

RR - INT
MANAGEMENT
Winter Ranges

January 27, 1941

ECOLOGICAL FACTORS AFFECTING RANGE FORAGE PLANTS

1. Field division: Range research.

2. Work project: Grazing management.

3. Line project: Winter ranges: Ecological factors affecting range forage plants.

4. Purpose: To determine (1) relative influence of various climatic and soil factors on forage production, (2) effect of climatic fluctuations on plant growth, and (3) adjustments in range management necessary to compensate for variability in forage yield.

5. Review of past work: Climate at the Desert Range Branch is extremely variable. Precipitation is erratic and varies greatly from season to season and from month to month. In 1933 June to October rainfall was only 0.33 inch; for the same period in 1936 it was 5.30 inches. Total precipitation was 3.50 inches in 1934 and 9.80 inches in 1938 with a 7-year average of 6.32 inches. Summer storms are frequently localized and often occur as torrential downpours, causing rapid run-off. Winter snowfall is also variable, frequently one locality will receive from 5 to 10 inches of snow when part of the same valley and adjacent areas will be suffering from lack of precipitation. Forage growth varies with fluctuation in precipitation; the period of precipitation seems to be more important in determining plant growth than does the total amount received. Some plants, such as Indian ricegrass, winterfat, shadscale, and black sage, grow best if winter and early spring precipitation is stored in the soil. Other plants, such as galleta grass, dropseed, grama grass, and Russian-thistle, depend almost entirely on summer rains. Because plant growth and winter snowfall is so extremely variable, range management for these areas must be flexible enough to meet the variations in forage production and grazing conditions which arise from the viscissitudes of climate.

6. Accomplishments during past year: In 1940 winter and early spring precipitation was above average but summer rains for the period May to August were very light and scattered, the total being only 0.45 inch. This is the driest growing season on record at the Desert. Precipitation for the period January to August was less than in the drought of 1934. Due to the favorable early spring precipitation shrubs and Indian ricegrass made

rapid early growth but became extremely dry and dormant during the hot summer. Russian-thistle, galleta grass, and other plants which depend on summer moisture failed to make any substantial growth. Forage production on areas where these plants were abundant was only 9 percent of the 1938 level.

7. Plans for next year: Study will be continued.

8. Date of completion: Indefinite.

9. Assignment: Selar S. Hutchings.

RR - INT
ARTIFICIAL REVEGETATION
Species Adaptability

January 27, 1941

SUITABILITY OF PLANT SPECIES FOR ARTIFICIAL REVEGETATION

1. Field division: Range research.

2. Work project: Artificial revegetation.

3. Line project: Suitability of plant species for artificial revegetation.

4. Purpose: To determine which forage species, whether native, introduced or produced by plant breeding, are best adapted to the various problem areas of the Intermountain region.

5. Review of past work: The progressive method of testing species adaptability i.e. from small plots with controlled competition to 1/100 per acre range plots under natural competition to large-scale planting, is proving very satisfactory.

   Species which have undergone these tests and have proved to be valuable in artificial revegetation are: Agropyron cristatum, A. inerme, A. pauciflorum, A. smithii, A. spicatum, A. subsecundum, Arrhenatherum elatius, Bromus carinatus, B. inermis, Elymus condensatus, E. glaucus, E. triticoides, Oryzopsis hymenoides, Poa ampla, and P. bulbosa.

6. Accomplishments during past year: The following species listed in last year's report as showing promise require further consideration before authoritative recommendations can be made: Bouteloua gracilis, Caragana arborescens, Elaeagnus angustifolia. Elymus canadensis, Hordeum bulbosum, Lupinus alpestris, L. ornatus, Poa nevadensis, P. secunda, Robinia pseudoacacia, Rosa fendleri, Stipa arida, S. columbiana nelsoni, S. viridula.

   Through seed collection and acquisition 337 species have been made available for testing and in addition to the species already listed the following appear promising in preliminary studies within the associated problem areas:

   1. Depleted and burned sagebrush areas: Agropyron elongatum, A. sibericum, Elymus junceus, E. triticoides simplex, Sitanion hystrix.

   2. Abandoned cultivated lands: (See depleted sage).

   3. Mountain brush areas: Dactylis glomerata, Festuca kingii, Melilotus alba, M. officinalis, Phleum pratense, Poa compressa.

4. Depleted aspen type: Dactylis glomerata, Festuca kingii, Lolium remotum, L. rigidum, Stipa columbiana, Vigiuera multiflora.

Although new legumes are continuously being tested for their adaptability as yet no definite recommendations can be made.

A species distribution study has been initiated to learn whether certain species of value for reseeding have fully occupied their potential ranges within the region.

Through cooperative agreements with local ranchers five native grasses hitherto unavailable commercially are being increased. These grasses are well adapted to reseeding but have been restricted in use because seed was not readily available.

7. Plans for next year: Routine observations will be continued on all planted species in order to investigate thoroughly their adaptability for artificial revegetation in this region. It is expected that, with the assistance of other agencies, additional species will be obtained for testing.

8. Date of completion: This project will be continued indefinitely to test newly acquired and developed species and strains.

9. Assignment: George Stewart, C. Kenneth Pearse, A. C. Hull, Jr., A. Perry Plummer, Richard M. Hurd, and Joseph H. Robertson.

RR - INT
ARTIFICIAL REVEGETATION
Site Factors

January 27, 1941

SITE FACTORS: SOILS, CLIMATE, ALTITUDE, AND OTHER FACTORS AFFECTING ARTIFICIAL REVEGETATION

1. Field division: Range research.

2. Work project: Artificial revegetation.

3. Line project: Site factors: Soils, climate, altitude, and other factors in relation to growth requirements of species used in artificial revegetation.

4. Purpose: To determine the effect of site factors on the growth and ultimate forage production of species used in artificial revegetation.

5. Review of past work: Physical and chemical soil characteristics influence results of revegetation. Accumulated evidence further substantiates the conclusion that Artemisia spp. and Chrysothamnus spp. have a definite suppressive influence on establishment and productiveness of reseeded species. Seeds of many native species require special pretreatment for successful germination.

6. Accomplishments during past year: Data show that heavy Bromus tectorum stands on most sites prevents the establishment of perennial grasses (with possible exception of Poa bulbosa) without special treatment to eliminate or reduce its competition. Poa bulbosa is holding its own in plots densely occupied by Bromus tectorum. Its aggressiveness is not so conspicuous as noted earlier.

Cold treatments lasting from 12 to 16 weeks at temperatures of 3 to 5°C. on seed of Amelanchier alnifolia, Balsamorhiza sagittata, Grayia spinosa, Leptotaenia multifida, Melica bulbosa, Purshia tridentata, and Stipa lettermani increased germination to over 80 percent where at standard temperatures germination was below 5 percent. Acid and mechanical scarification treatments on seed of Oryzopsis hymenoides increased germination from less than 5 to more than 80 percent. Untreated seed, if allowed to remain in the ground for 1 year (or more) has produced good stands on some sites.

Studies to determine the manner by which Artemisia tridentata suppresses reseeded species are underway. A recent study shows that retarded root development in the early seedling stage and slow germination are probably causes of failure of some of the native xerophytic species.

7. Plans for next year: Continued study will be directed toward the development of practical methods of treating refractory seeds for range planting. The feasibility of increasing available nitrogen in soils through the use of legumes will be investigated in greenhouses and field tests. Studies to determine the degree to which sagebrush suppresses the establishment of grasses will be continued and enlarged to provide basic data as soon as possible for the intelligent reseeding of sagebrush areas.

8. Date of completion: Indefinite.

9. Assignment: A. C. Hull, Jr., C. Kenneth Pearse, George Stewart, Joseph H. Robertson, A. Perry Plummer, Richard Hurd, and C. Allan Friedrich.

RR - INT
ARTIFICIAL REVEGETATION
Methods

January 27, 1941

METHODS: TIME, DEPTH, CULTURE, PRACTICABILITY AND COST OF PLANTING

1. Field division: Range research.

2. Work project: Artificial revegetation.

3. Line project: Methods: Time, depth, culture, practicability and cost of planting.

4. Purpose: To determine the most practical time and methods of planting and subsequent treatment in the revegetation of depleted ranges.

5. Review of past work: Drilling usually is the most desirable method of planting where conditions are suitable. Elsewhere, harrowing and furrowing followed by brush dragging and in some cases by sheep trampling, are methods adapted to particular sites. A sidehill drill has been developed and is successful for seeding slopes as steep as 70 percent. Fall planting has been most successful on the majority of sites. Successful stands of the species being used in range plantings have been obtained with seedings of 5 to 15 pounds per acre. The rate of seeding required to produce a successful stand depends upon size of seed, percent germination, method of planting, and soil and climatic conditions. Satisfactory stands of Agropyron cristatum have been obtained under some conditions from plantings as low as 2 pounds per acre. Optimum depth of planting varies from $\frac{1}{4}$ inch to $1\frac{1}{2}$ inches, depending upon the species sown, climate and site conditions, and season of sowing.

6. Accomplishments during past year: Results from season and depth of planting studies at five dissimilar locations show that season, site, and precipitation are factors which complicate and necessitate specific recommendations for each site. Results over a period of years will be necessary before valid conclusions may be drawn.

   In indole acetic acid treatments on nine species, three of these (Rosa fendleri, Clematis hirsutissima, and Ribes aureum) have given statistically significant increases in percentage of rooted cuttings and extent of root development. Application of this method to the field has so far been unsuccessful but the techniques are being further investigated to make the method feasible for field plantings.

Studies in depleted sagebrush areas show that burning under controlled conditions has practical application for eliminating sage and other brush so that reseeded species may be established. Preliminary trials indicate several promising methods for large scale planting: (1) Railing down mountain brush and sagebrush, thereby reducing competition and providing litter beneficial to seedling plants. (2) Use of a Wheatland plow on sagebrush and weed stands to eliminate the competition and at the same time make a choice seedbed and leave brush on ground to provide protection for seeded species. (3) Use of Killifer disk to eliminate competition from weeds such as wyethia and leontodon. (4) A disk-harrow has been successfully used to cover seed on areas too brushy or rocky for drilling. (5) Ripping with a road scarifier not only loosens the ground to allow absorption of moisture and facilitate seed covering, but reduces competition by destroying brush and weeds.

Hand devices for collections and cleaning of small lots of native seeds have been constructed and successfully used. Garden tractors have been adapted for weeding and for planting experimental plots to simulate methods used in large-scale plantings. Adjustments have been made for the attachment of various implements to make the garden tractors very useful for weeding nursery plots.

7. Plans for next year: Refinement of present methods and development of new methods for reseeding in various vegetational types found in Region 4 will be continued. The existing detailed studies on season-depth will be continued. Two new season-depth studies will be initiated, one in the aspen zone and the other in the subalpine. Preliminary studies will be inaugurated to determine extent of damage to reseeded species on gopher infested areas. Refinement of machinery for economical reseeding of range lands will be continued.

8. Date of completion: Indefinite.

9. Assignment: C. Kenneth Pearse, A. C. Hull, Jr., A. Perry Plummer, C. Allan Friedrich, Richard M. Hurd, Joseph H. Robertson.

RR - INT
ARTIFICIAL REVEGETATION
Plant Breeding

January 27, 1941

PLANT BREEDING: SELECTION AND HYBRIDIZATION

1. Field division: Range research.

2. Work project: Artificial revegetation.

3. Line project: Plant breeding: Selection and hybridization (conducted in cooperation with the Bureau of Plant Industry and the Utah State Agricultural Experiment Station, the Bureau of Plant Industry acting as leader and prosecuting the detailed work).

4. Purpose: To produce improved strains of range plants by selection. To determine the pollen production and quality, and pollination and seeding habits of range plants as a basis for hybridization studies; and to produce improved strains of range plants by hybridization.

5. Review of past work: Several hundred individual plants of the more promising species for revegetation work have been studied and selections have been made on the basis of leafiness, seed production, erectness and rate of spread of rhizomes. Mass selection strains of Bromus inermis and Agropyron smithii planted at the dry land nurseries are becoming established. A supply of self-pollinated seed has been obtained by means of bagging in order to provide homozygous material with which to begin hybridization studies. About three hundred individual plants of Sitanion hystrix have been started and observation looking toward selection and hybridization of this species are being made at dry land nurseries.

   Studies of strains of Agropyron cristatum and Bromus inermis have shown great variations in growth habits, yield, and ability to produce seed. Some of these differences seem to be hereditary and others the result of environmental conditions.

6. Accomplishments during past year: As yet no noticeable differences occurring in the first growing season could be detected among the various strains of Agropyron cristatum, A. inerme, A. pauciflorum, A. smithii, A. spicatum, Bromus inermis, Poa ampla, P. pratensis. To find the possible effect that the year may have upon establishment of the various strains and species the same strains were replanted this year.

A wide variation within some of the important native forage species in this region has been observed in the field. To determine whether this variability is due to site factors or genetic differences an extensive seed collection program was initiated to provide a number of seed sources for selected species. In one field location a preliminary study was started which included all available seed sources of each selected species. The species planted together with the number of seed sources are as follows: Agropyron pauciflorum (12), A. smithii (5), A. spicatum (8), A. subsecundum (5), Bromus carinatus (9), and Elymus glaucus (3).

Preliminary investigative work is being conducted to determine whether a giant form of Agropyron spicatum found in Nevada is a polyploid.

In an attempt to secure strains of Agropyron cristatum that are best adapted to this region, seed from 25 seed sources are being tested. Seedlings are being grown under greenhouse conditions and later will be transplanted to the field for further observation.

7. Plans for next year: A series of experiments designed to study variability in relation to source of seed will be initiated throughout the region. Selection and nursery tests are being continued. Additional work will be conducted on hybridization as soon as conditions warrant.

8. Date of completion: Indefinite.

9. Assignment: Wesley Keller, Bureau of Plant Industry, Advisory; George Stewart and C. Kenneth Pearse, Forest Service.

INFLUENCES

RI - INT
STREAM FLOW
Woodland
Great Basin

January 27, 1941

STREAM FLOW (TREE, SHRUB, GRASS)

1. Field division: Forest and range influences.

2. Work project: Influence of natural vegetation on stream flow.

3. Line project: Woodland cover: Relation of woodland cover (tree, shrub, grass) to stream flow.

4. Purpose: To determine for the mixed brush-woodland watersheds of the Wasatch Mountains the management practices that will assure the greatest yield in quantity and quality of stream flow and maintain soils in place.

5. Review of past work: In the Great Basin about 80 percent of stream flow originates from melted snow on range lands above 7,000 feet elevation. Spring run-off, when demand by users is low, amounts to 65 to 90 percent of the total annual flow, whereas July, August, and September flow, when demand is high, may not exceed 6 percent of the annual yield. Surveys indicate that quality of stream flow has been changed as a result of excessive watershed utilization. In many instances destructive mud-rock flows have done great damage to valley property and potential flood areas continue to threaten the social and economic well-being of many communities.

   The Wasatch Stream Flow Laboratory, comprising about 4,800 acres of which 2,025 consists of 11 watersheds with permanent streams, has been established in the Wasatch Mountains of northern Utah. Automatic stream gaging stations have been established on 6 north-facing watersheds and stream gaging stations on 5 south-facing watersheds of 1,865 acres are nearing completion. Influence of plant type and density on surface run-off phases are being made on 16 surface run-off plots.

6. Accomplishments during past year: Stream gaging stations on 5 south-facing experimental watersheds, and on Farmington Creek have been completed and approaches to all Venturi-trapezoidal type flumes have been constructed to minimum standards. Year-long snow and rain gages have been substituted for standard rain gages on experimental watersheds. Plant inventory of 5 south-facing watersheds was completed, and 5 miles of contour trails were constructed to review these areas.

7. Plans for next year: Complete flume approaches, make preliminary flow analysis of all experimental streams. Make check calibration on all flumes.

8. Date of completion: Indefinite.

9. Assignment: A. R. Croft and B. C. Goodell.

RI - INT
STREAM FLOW
Herbaceous Cover

January 27, 1941

STREAM FLOW (HERBACEOUS RANGE, UTAH)

1. Field division: Forest and range influences.

2. Work project: Influence of natural vegetation on stream flow.

3. Line project: Grassland: Role of grassland in influencing stream behavior.

4. Purpose: To determine for herbaceous range lands of Utah the management practices required for maintaining plant and soil mantle conditions favorable for maximum yields and most useful seasonal distribution of stream flow.

5. Review of past work: Increased density of herbaceous range cover and decreased intensity of trampling by grazing on 10-acre A-B watersheds at Great Basin Branch Station reduced peak-flow discharges from summer storms during the period 1915-1929. Continued measurements with treatment reversed indicates the condition of plant and soil mantle more important than such factors as size, shape, slope, and gully pattern. Six 1/10-acre run-off plots were established at the Great Basin Branch Station in 1935 for obtaining more refined measurements of the effect of range use on run-off.

6. Accomplishments during past year: Five tributaries in head of Ephraim Creek were equipped with stream gaging stations last winter. Spring peak-flow discharges from these areas were found to be due principally to seepage flow and channel interception. Run-off from A-B watersheds during early summer storms was much less than following similar storms late in summar, apparently due to physical soil changes. Infiltration tests on trenches show that permeability of "B" horizon determines infiltration capacity of soil mantle during prolonged snow melt period, the presence of deep rooted grasses greatly increasing permeability of the "B" horizon.

7. Plans for next year: Continue A-B study and records on new Ephraim Creek gaging stations, including run-off - infiltration relationships. Install climatological instruments on new watersheds, calibrate new gaging stations, and complete installation of gaging station at Bluebell Flat.

8. Date of completion: Snow melt phases, 1943; stream flow, indefinite.

9. Assignment: A. R. Croft.

RI - INT
STREAM FLOW
Grassland

January 27, 1941

STREAM FLOW (BUNCHGRASS-GRANITIC SOIL RANGE, IDAHO)

1. Field division: Forest and range influences.

2. Work project: Influence of natural vegetation on stream flow.

3. Line project: Grassland: Role of grassland in influencing stream behavior.

4. Purpose: To determine for bunchgrass-granitic soil range lands of southern Idaho, the management practices required for obtaining plant and soil conditions that will yield maximum quantities of usable stream flow.

5. Review of past work: The quantity of undesirable silt-laden surface run-off on the Boise River watershed has been found to increase with deterioration of the range cover through excessive grazing. Surveys and controlled measurements with artificial rainfall apparatus show that surface run-off increases directly with retrogression of the range cover, soil disturbance, decreased organic matter content of the soil, increased rainfall intensity, and increase in slope steepness. In 1935 two 10-acre and in 1937 three 200-acre watersheds were equipped with gaging stations to determine the extent to which ranges in this area can be grazed without adversely affecting usable stream flow.

6. Accomplishments during past year: Analysis of infiltration measurements show that true flood source areas occur as restricted spots having low infiltration rates within all range types. Infiltration rates on "low" flood source areas averaged about twice those on "high" flood sources. It is believed newer infiltrometer equipment which will more nearly simulate rainfall impact will show greater differences in infiltration rates between low and high flood source areas and will also indicate significant differences between range types.

7. Plans for next year: (a) Continue watershed operations, and (b) determine infiltration rates of high and low flood sources within five range types by new type infiltrometer apparatus.

8. Date of completion: Watershed phase indefinite; infiltration phase, 1941.

9. Assignment: George W. Craddock and C. Allan Friedrich.

RI - INT
WATER UTILIZATION
Range forage

January 27, 1941

WATER UTILIZATION (BUNCHGRASS-GRANITIC SOIL RANGE, IDAHO)

1. Field division: Forest and range influences.

2. Work project: Water utilization by vegetation.

3. Line project: Range forage: Relation of water requirements of range forage species.

4. Purpose: To determine on the bunchgrass-granitic soil range lands of southern Idaho the kind of cover that is required for minimizing evapo-transpiration water losses.

5. Review of past work: A battery of six 2-milacre lysimeters was constructed at Bannock Creek in 1933 and filled with 4 feet of tamped soil. Tanks were refilled with untamped homogeneous soil in 1935 and maintained in bare condition. In 1937 two each were planted to climax bunchgrasses, subclimax herbs, and annual weeds. Further planting has been done each year to attain desired differences in composition and density, while obtaining records of precipitation and both surface and seepage water yield.

6. Accomplishments during past year: Analysis of past 5-year period shows average annual water loss from lysimeters to be about 50 percent, or 12.08 inches as compared to 23.35 inches of precipitation. All water yield occurred following spring snow melt, 99 percent being seepage. Supplemental study at Arrowrock last year showed soil moisture was depleted to wilting coefficient from 1 to 2 weeks earlier on artificially reseeded, improved range than on deteriorated annual weed range. Because soil moisture fell below wilting coefficient during summer months on both types of range suggests annual evapo-transpiration losses essentially similar since same amount of winter recharge will be needed to bring both ranges to free water stage. This indicates improved range conditions will not result in consumptive water losses.

7. Plans for next year: (a) Maintain lysimeter in operation, and (b) expand soil moisture determinations to include measurements at Bannock Creek Lysimeter Basin Area.

8. Date of completion: Lysimeter phase indefinite; soil moisture phase, 1941.

9. Assignment: George W. Craddock and C. Allan Friedrich.

RI - INT
SOIL STABILIZATION
Watersheds

January 27, 1941

SOIL STABILIZATION (BUNCHGRASS-GRANITIC SOIL RANGE, IDAHO)

1. Field division: Forest and range influences.

2. Work project: Stabilization of soils.

3. Line project: Watersheds: Relation of forest, brush, grassland cover, and management practices to erosion and soil stability and to quality and usability of water.

4. Purpose: To determine on bunchgrass-granitic soil range lands of southern Idaho: (1) The range utilization practices required for maintaining soils in place, and (2) the improvement measures needed to stabilize soil on eroding areas.

5. Review of past work: Widespread accelerated erosion on the Boise River Watershed has been found to be directly related to retrogression of the range cover and soil disturbance due to excessive grazing, and to rainfall intensity and slope steepness. In 1935 two 10-acre watersheds at Bannock Creek and in 1937 three 200-acre watersheds at Arrowrock were established to determine the extent to which ranges in this area can be grazed without disturbing the soil, but thus far it has been impossible to equip the latter watersheds with silt-measuring devices. In 1937 erosion was measured on deteriorated range plots with artificial rainfall apparatus with a view toward remeasuring erosion after the plots were artificially reseeded.

6. Accomplishments during past year: High intensity storms in September caused much (unmeasured) erosion on the deteriorated triplicate watersheds at Arrowrock, and practically no erosion on the paired, less seriously deteriorated watersheds at Bannock Creek. Unsatisfactory establishment of artificially reseeded grasses precluded making scheduled remeasurement of erosion on plots.

7. Plans for next year: Continue erosion measurements on the paired watersheds.

8. Date of completion: Indefinite.

9. Assignment: George W. Craddock and C. Allan Friedrich.

RI - INT
SOIL STABILIZATION
Watersheds
Great Basin

January 27, 1941

SOIL STABILIZATION (FOREST, BRUSH, GRASSLAND, UTAH)

1. Field division: Forest and range influences.

2. Work project: Stabilization of soil.

3. Line project: Watersheds: Relation of forest, brush, grassland cover, and management practices to erosion, and soil stability and quality and usability of stream flow.

4. Purpose: To determine on mixed forest-brush land in the Wasatch Mountains the management practices which will maintain soil stability and usable stream flow.

5. Review of past work: Extensive observational and limited research data indicate excessive accelerated erosion throughout the region, on mixed forest, brush, and grasslands, often seriously affecting quality of water yield. Data from small watersheds and plots, together with extensive observations, indicate that plant cover is the key to the erosion situation. Soil analyses of approximately 2,000 permanent plots covering all study areas, and of about 2,000 plots along 175 miles of transect covering 21 other localities show that accelerated erosion reduces organic matter, total nitrogen, and moisture equivalent as much as 70, 39, and 67 percent, respectively. Methods for qualitative and quantitative determinations of accelerated erosion have been refined. A soil survey of 7 experimental watersheds and 22 experimental plots involving permanent locating and marking more than 2,000 sample plots has been made.

6. Accomplishments during past year: A soil inventory of 5 south-facing experimental watersheds has been made. Laboratory analysis of all samples from watersheds and plots is progressing satisfactorily. Assistance was given to Administration in developing erosion survey plans and conducting soil study training schools.

7. Plans for next year: Confine efforts to laboratory analysis of soils from experimental watersheds and plots.

8. Date of completion: Indefinite.

9. Assignment: A. R. Croft, and B. C. Goodell.

RI - INT
FLOOD CONTROL
Watershed Survey

January 27, 1941

FLOOD CONTROL PRELIMINARY EXAMINATION AND REPORT (COMMITTEE 17-A)

1. Field division: Flood control surveys.

2. Work project: Flood control surveys.

3. Line project: Preliminary examinations: Examination of watersheds to determine existence of flood problems.

4. Purpose: To determine the existence of flood problems and the need for and character and cost of detailed flood control surveys on watersheds within the Bonneville Lake Basin of the Great Basin and the Upper Colorado River drainage basins.

5. Review of past work: Participated in public hearings in cooperation with the U. S. Corps of Engineers on the Green River in Wyoming, tributaries of the Upper Colorado River, and tributaries of the Great Basin in Utah and Nevada. Completed preliminary examination report upon the Sevier Lake Watershed.

6. Accomplishments during past year: Completed preliminary examination report on the Great Salt Lake Watershed and initiated a report upon the Weber River watershed.

7. Plans for next year: Tentatively planned to initiate an overall preliminary examination report upon the entire Bonneville Lake Basin, including area already covered extensively within the Great Salt Lake Watershed, with a view toward initiating a detailed survey early in 1942 on one of the four following units: (1) Wasatch Front tributaries, (2) Weber River, (3) Provo River (4) Bear River, and an overall report upon the upper Colorado River.

8. Date of completion: Interim report and work plan for detailed survey on selected unit in fall of 1941; complete P. E. report on Bonneville Lake Basin and upper Colorado River by June 1942.

9. Assignment: Field Coordinating Committee 17-A

Field Working Committee 17-A
George W. Craddock, Chairman (FS)
Arthur Fife (SCS)
Carl F. Wehrwein (BAE)

RI - INT
FLOOD CONTROL
Watershed Surveys

January 27, 1941

FLOOD CONTROL PRELIMINARY EXAMINATION AND REPORTS (COMMITTEE 17-B)

1. Field activities: Flood control surveys.

2. Work project: Flood control surveys.

3. Line project: Preliminary examinations: Examinations of watersheds to determine existence of flood problems.

4. Purpose: To determine the existence of flood problems and the need for and character and cost of a detailed flood control survey on watersheds within the Upper Snake River drainage basin.

5. Review of past work: Participation in Public Hearings in cooperation with the U. S. Corps of Engineers on (1) the Snake River and its tributaries in Idaho, Washington, and Oregon, and (2) the Owyhee River in Nevada and Idaho.

6. Accomplishments during past year: Revamped early tentative draft of report on the Weiser River based on new hydrologic data.

7. Plans for next year: Complete preliminary examination report upon the Weiser River after incorporating additional basic data now being made available by the U. S. Bureau of Reclamation, with recommendations for a program of advanced studies in lieu of a detailed survey in 1941; and initiate preliminary examination report upon the Snake River (above Idaho Falls).

8. Date of completion: Weiser P. E. June 1941; Snake River, June 1942.

9. Assignment: Field Coordinating Committee 17-B

Field Working Committee 17-B
George W. Craddock, Chairman (FS)
H. M. Wanser (SCS)
Leonard M. Hill (BAE)

RI - INT
FLOOD CONTROL
Watershed Survey

January 27, 1941

FLOOD CONTROL PRELIMINARY EXAMINATION AND REPORTS (COMMITTEE 17-C)

1. Field division: Flood control surveys.

2. Work project: Flood control surveys.

3. Line project: Preliminary examinations: Examination of watersheds to determine existence of flood problems.

4. Purpose: To determine the existence of flood problems and the need for and character and cost of a detailed flood control survey on watersheds within the Lahontan Lake Drainage Basin.

5. Review of past work: Participation in Public Hearings in cooperation with the U. S. Corps of Engineers on the Humboldt River and other tributaries of the Lahontan Lake Drainage Basin.

6. Accomplishments during past year: No work on this area.

7. Plans for next year: None proposed

8. Date of completion: Indefinite.

9. Assignment: Field Coordinating Committee 17-C

Field Working Committee 17-C
George W. Craddock, Chairman (FS)
(SCS)
Carl F. Wehrwein (BAE)

RI - INT
FLOOD CONTROL
Watershed Surveys

January 27, 1941

BOISE RIVER WATERSHED SURVEY

1. Field division: Flood control surveys.

2. Work project: Flood control surveys.

3. Line project: Watershed surveys: Detailed survey of approved watersheds for preparing action program.

4. Purpose: To determine the kind, cost, and benefits of measures needed to be applied for flood control, waterflow retardation, and prevention of soil erosion on the watershed lands of the Boise River, Idaho.

5. Review of past work: Interim report covering recommendations for applications of remedial measures on Willow Creek Work Unit submitted in fall of 1938.

6. Accomplishments during past year: Completed and submitted detailed survey report with recommendations for a program of watershed improvement measures in the interest of flood control and conservation coordinated with and supplementary to a multiple-purpose dam project recommended by the U. S. Corps of Engineers.

7. Plans for next year: Indefinite.

8. Date of completion: Indefinite.

9. Assignment: Field Coordinating Committee 17-B
Field Working Committee 17-B
Project Leader _____ (vice T. H. Van Meter - F.S.)

RI - INT
FLOOD CONTROL
Watershed Surveys

January 27, 1941

SEVIER LAKE WATERSHED SURVEY

1. Field division: Flood control surveys.

2. Work project: Flood control surveys.

3. Line project: Watershed surveys: Detailed surveys of approved watersheds for preparing action program.

4. Purpose: To determine the kind, cost, and benefits of measures needed to be applied for flood control, waterflow retardation, and prevention of soil erosion on the watershed lands of the Sevier Lake Watershed, Great Basin, Utah and Nevada.

5. Review of past work: New project.

6. Accomplishments during past year: Field work largely completed on past damages, factors contributing to flood hazard and requirements of remedial program based on intensive study of 20 sample tributaries and extensive investigations covering remainder of 18,000 square milearea. Analysis of field data now under way including calculation of expected future damages and effects of remedial measures.

7. Plans for next year: Complete Sevier Lake Survey. Extension of survey report deadline to December necessary in order to obtain additional essential data on infiltration, sedimentation, and remedial measures during the workable field season.

8. Date of completion: December 1941.

9. Assignment: Field Coordinating Committee 17-A.
Field Working Committee 17-A
Project Leader: E. C. Sanford (FS)

FOREST ECONOMICS

RE - INT
RANGE ECONOMICS

January 27, 1941

AREA STUDIES IN RANGE ECONOMICS

1. Field division: Forest economics.

2. Work project: Range economics.

3. Line project: Economic study of central Utah area around the Manti and Fishlake National Forests.

4. Purpose: To determine for the central Utah area the economic and social effects of different alternatives of policy in the use and management of public lands for grazing by farm and ranch livestock.

5. Review of past work: The preliminary phases of this study concerned themselves with developing a knowledge of the area and its general problems.

6. Accomplishments during past year: The work during the past year has developed the following:

   (1) A complete picture of all the public land grazing privileges in the area on an operating unit basis.

   (2) A 90 percent sample of all the farm and ranch units in the area showing their organization, livestock numbers, and gross income from crops and livestock.

   (3) An inventory of the present amount of public land grazed by seasons.

   (4) General information on the area such as data on population, climate, income other than from agriculture, etc.

   (5) Information showing the relative efficiency of the different sizes and types of livestock enterprises. (This information is not sufficiently clear-cut and additional sources will be tapped this coming year to round it out.)

   (6) Maps of the movements of livestock in the area from the different seasonal ranges and ownerships of range.

7. Plans for next year: Plans for the coming year may be listed under three headings as follows:

   (1) Development of a picture of the feed resources of the area both from ranges and harvested feed crops.

(2) A more complete knowledge of the efficiency of the different types and sizes of livestock enterprises of the area.

(3) Analysis of all data for the area and preparation of a final report.

8. Date of completion: The manuscript on this study will be ready for review by July or August of 1941.

9. Assignment: Mont H. Saunderson, and Arthur H. Roth, Jr.

RE - INT
RANGE ECONOMICS

January 27, 1941

AREA STUDIES IN RANGE ECONOMICS

1. Field division: Forest economics.

2. Work project: Range economics.

3. Line project: Area economic study of northeastern Nevada being made in cooperation with other Federal and Nevada state agencies.

4. Purpose: To ascertain that use of the natural resources of northeastern Nevada which will lead to the greatest and most enduring prosperity of the area.

5. Review of past work: Prior to the past year the ranch economics and land use data were collected and analyzed in a cursory manner and range and soil surveys undertaken.

6. Accomplishments during past year: Most of the work last year was devoted to completion of the field work on the range survey. A few meetings of the committee on ranch economics and allied problems were held, but analysis of data was deferred until completion of the range survey compilations.

7. Plans for next year: At least one report on some economic phase of the study will be issued by June 30, 1941. It is planned to have the manuscript (or all manuscripts) on this study completed by the end of 1941.

8. Date of completion: It is planned to complete the manuscript (or manuscripts) on this study by the end of 1941.

9. Assignment: Mont H. Saunderson.

RE - INT
RANGE ECONOMICS

January 27, 1941

AREA STUDIES IN RANGE ECONOMICS

1. Field division: Forest economics.

2. Work project: Range economics.

3. Line project: A graphic summary of grazing on the public lands of the Intermountain Region.

4. Purpose: To set forth in graphic form the public land grazing resources of this region, their use, and distribution of use.

5. Review of past work: No inventory of the public land grazing resources and their use has ever been made before in this region.

6. Accomplishments during past year: Part I of this graphic summary entitled "Regional Aspects of Range Resources and Trends in Range Use" was completed and published in mimeographed form. Part II of this summary entitled "Seasonal Use Relationships of Land in the Production of Range Livestock" has been reviewed by the Washington Office, revised, and is now in Washington for final review. As soon as Part II is returned it will be mimeographed and released.

7. Plans for next year: Part III of the graphic summary, "Present Distribution of the Public Land Grazing Resources to the Different Sizes and Types of Livestock Enterprises" will be offered for review during the latter half of 1941.

8. Date of completion: It is proposed to have all the major work on this graphic summary completed by the end of 1941.

9. Assignment: Arthur H. Roth, Jr.

A P P E N D I X

PUBLICATIONS

I. Publications during the calendar year 1940

A. Departmental publications

Stewart, George, W. P. Cottam, and Selar S. Hutchings. Influence of unrestricted grazing on northern salt desert plant associations in western Utah. Jour. Agr. Res. v. 60 (5):289-316, illus. 1940.

B. Outside publications (in scientific and professional journals, etc.)

Clark, Ira. Good cattle - good grass go together. Hereford Jour. Jan. 15, 1940.

Cottam, W. P., and Stewart, George. Plant succession as a result of grazing and of meadow dessication by erosion since settlement in 1862. Jour. Forestry, v. 38(8): 613-626. 1940.

Craddock, George W. Forestry and water. Jour. Forestry, v. 38(2): 141-146, 1940.

Croft, A. R. Relationship of soil profile to infiltration rate. Proceedings Western Society of Soil Science. 1940.

Hull, A. C., Jr. Bulbous bluegrass, valuable for reseeding Intermountain ranges. The National Wool Grower, v. 30(8): 32, 1940.

_____, and Martin, T. L. A study of physical and chemical characteristics of soils under sagebrush, shadscale, and winterfat. Proc. Utah Acad. Science, Arts and Letters. (Report 1939) v. 16: 39.

_____, and Shaw, Seth T. Respiration of bulbous bluegrass bulbils. Proc. Utah Acad. Science, Arts and Letters. v. 17: 14. 1940.

Maki, T. Ewald. Significance and applicability of seed maturity indices for ponderosa pine. Jour. Forestry, v. 38(1): 55-60. 1940.

Mowat, Edwin L. Damage by logging and slash disposal in Idaho ponderosa pine. Jour. Forestry 38(3):247-255. 1940.

Pechanec, Jos. F. Forest Service Range Research Seminar. Ecology, v. 21, no. 3: 422-424. 1940.

_____, and Stewart, George. Sagebrush-grass range sampling studies: size and structure of sampling unit. Jour. Amer. Soc. Agron. v. 32, no. 9, 1940.

Saunderson, Mont H. Western wild lands. In Land Policy Review, v. 3, no. 8:31-33. 1940.

_____. A comparison of Idaho and Utah range sheep operations. National Wool Grower, Nov. 1940.

_____. Some economic aspects of western range-land conservation. Jour. Land & Pub. Util. Econ. May 1940.

_____. Land costs and investment standards for Intermountain sheep ranch operations. National Wool Grower v. 30(4):11-13. 1940.

Snow, Edna, and Stewart, George. A preliminary report of the algae of Mirror Lake. Utah Acad. Science, Arts and Letters, 16:113-115. 1939.

Stewart, George. Forest Service Range Research Seminar. Amer. Soc. Agron. Jour, v. 32, no. 3, March 1940.

_____, and Pearse, C. Kenneth. Reseeding undertaking vital to West's welfare: cost less than $6 an acre. Standard-Examiner, Feb. 4, 1940. Industrial Progress number.

C. Miscellaneous mimeographed reports

Roth, Arthur H., Jr. A graphic summary of grazing on the public lands of the Intermountain region. Part I. Regional aspects of range resources and trends in range use. March 15, 1940.

II. Manuscripts intended for departmental publication between January 1, 1941 and June 30, 1941

Ellison, Lincoln. A comparison of methods of quadratting shortgrass vegetation. Jour. Agr. Res. 20 pp., 6 illus.*

McCarty, E. C., and Price, Raymond. Growth and carbohydrate food ratios of important range forage plants and their reactions to clipping and grazing treatments. USDA Tech. Bul. 50 pp., illus.

Stewart, George, Pechanec, Joseph F. and Pickford, G. D. Effect of sagebrush removal by fire on native spring-fall range in southeastern Idaho. USDA Tech. Bul. 30 pp., 12 illus.

July 1, 1941 and June 30, 1942

Clark, Ira and _____. Range use indicators and utilization standards for Intermountain range lands. USDA Farmers' Bul. 25 pp., illus.

Hutchings, Selar S., and Stewart, George. Palatability and utilization of desert vegetation as influenced by climate, season of use, and composition of plant cover. Jour. Agr. Res. 20 pp., illus.

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*Cooperative paper. George Stewart and Joseph F. Pechanec will represent the Intermountain Station. The University of Idaho will designate men to represent their part in the publication.

STATION PERSONNEL - C.Y. 1940

ADMINISTRATION

Regular

Reed W. Bailey	Director
Walter E. Mann	Administrative Assistant
Marguerite A. Israelson	Clerk
Herbert Burrell	Clerk
Leona H. O'Donnell	Asst. Clerk
Hazel B. Ballinger	Sr. Stenographer
Yvonne E. Wheat	Jr. Clerk-Steno.
Signe Ruh Otterson	Jr. Librarian (Coop. R-4)

Temporary

Denzil L. Black	Jr. Clerk

RANGE INVESTIGATIONS

Grazing Management

Regular

George Stewart	Sr. Forest Ecologist
Lincoln Ellison	Range Examiner
Joseph F. Pechanec	Assoc. Forest Ecologist
Selar S. Hutchings	Asst. Forest Ecologist
Ira Clark	Asst. Conservationist

Temporary

Harold E. Gibson	Jr. Field Assistant
Paul E. Hansen	Jr. Field Assistant
Ray H. Bjarnson	Under Asst. Tech.
Virgil C. Peterson	Jr. Agricultural Aid
J. Pershing Blaisdell	Jr. Agricultural Aid
Keith V. Barron	Jr. Agricultural Aid
Charles E. Poulton	Jr. Agricultural Aid

Artificial Reseeding

Regular

George Stewart	Sr. Forest Ecologist
C. Kenneth Pearse	Conservationist
Alvin C. Hull, Jr.	Jr. Range Examiner
A. Perry Plummer	Jr. Range Examiner
Richard M. Hurd	Jr. Range Examiner
Joseph H. Robertson	Jr. Range Examiner

Temporary

W. Harold Hirst	Asst. Technician
A. Riggs Murdock	Asst. Technician
Grant A. Harris	Jr. Field Assistant

FOREST ECONOMICS

Range Economics

Regular

Mont H. Saunderson	Sr. Economist
Arthur H. Roth	Asst. Economist

Temporary

Durrell E. Evans	Agricultural Aid

FOREST MANAGEMENT

Silviculture

Regular

Edwin L. Mowat	Asst. Silviculturist
V_____	Jr. Forester

Temporary

Edmund L. Barraclough	Under Asst. Tech.
Henry L. Ketchie	Jr. Field Assistant
J. Keith Melvin	Jr. Agricultural Aid

FOREST AND RANGE INFLUENCES

Influence of Natural Vegetation on Stream Flow

Regular

George W. Craddock	Sr. Range Examiner
A. Russell Croft	Conservationist
Bertram C. Goodell	Jr. Forester
James P. Thorne	Jr. Technologist
C. Allan Friedrich	Jr. Range Examiner

Temporary

Howard R. Foulger	Asst. Field Assistant
Harry W. Pledger	Foreman C&M
Richard B. Marston	Jr. Agricultural Aid
John W. Quayle	Jr. Field Assistant
Eldon Earl Meik	Under Asst. Tech.
Jack R. Gidney	Engineering Aid

FLOOD CONTROL SURVEYS

Supervision and Preliminary Examinations

Regular

Reed W. Bailey	Director
George W. Craddock	Sr. Range Examiner
Cleve H. Milligan	Asso. Hydraulic Eng.
Byron F. Thurmond	Prin. Eng. Draftsman

Sevier Lake Watershed Survey

Regular

George W. Craddock	Sr. Range Examiner
Earl C. Sanford	Forester
Harold H. Price	Assoc. Range Examiner
George L. Ballinger	Asst. Topographic Drafts.
Agnes M. Medvit	Jr. Clerk-Steno.
Byron F. Thurmond	Prin. Eng. Draftsman
Allan Q. Warnock	Clerk
Lowell Woodward	Jr. Range Examiner
Marshall K. Wood	Asst. Range Examiner

Temporary

Gustin V. Leffler	Jr. Agricultural Aid
Fred S. Rabe	Jr. Laboratory Helper

FOREST AND RANGE BIOLOGY

Clarence M. Aldous (Cooperation Fish and Wildlife Service)	Assoc. Biologist